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**Arun**

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(54) **SYSTEMS AND METHODS FOR SCALABLE ASYNCHRONOUS COMPUTING FRAMEWORK**

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(51) **Int. Cl.**

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| ***G06F 9/48*** | (2006.01) |
| ***H04L 29/08*** | (2006.01) |
| ***G06F 3/14*** | (2006.01) |
| ***G06T 7/00*** | (2006.01) |
| ***G06T 15/08*** | (2011.01) |
| ***G06T 17/10*** | (2006.01) |
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| ***G06F 9/445*** | (2006.01) |

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CPC ..... ***G06F 9/4881*** (2013.01); ***G06F 3/1438*** (2013.01); ***G06F 3/1446*** (2013.01); ***G06F 3/1454*** (2013.01); ***G06F 9/445*** (2013.01); ***G06T 1/20*** (2013.01); ***G06T 7/0046*** (2013.01); ***G06T 15/005*** (2013.01); ***G06T 15/08*** (2013.01); ***G06T 17/10*** (2013.01); ***H04L 67/1002*** (2013.01); *G06T 2200/16* (2013.01); *G06T 2207/10024* (2013.01); *G06T 2210/52* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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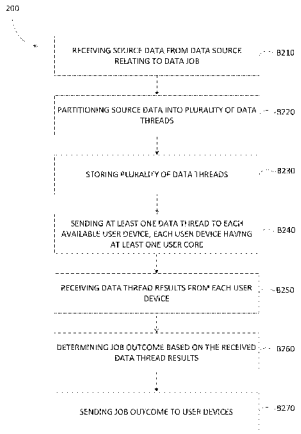
(57) **ABSTRACT**

Systems and methods are described for a distributed data processing method, including, but not limited to: receiving, by a backend device, source data; partitioning, by the backend device, the source data into a plurality of data threads; sending, by the backend device, at least one of the plurality of data threads to each of a plurality of user devices; and determining, by the backend device, a job outcome for the source data based on a plurality of data thread results, each of the plurality of data thread results is determined by one of the plurality of user devices based on the at least one of the plurality of data threads.

**21 Claims, 10 Drawing Sheets**



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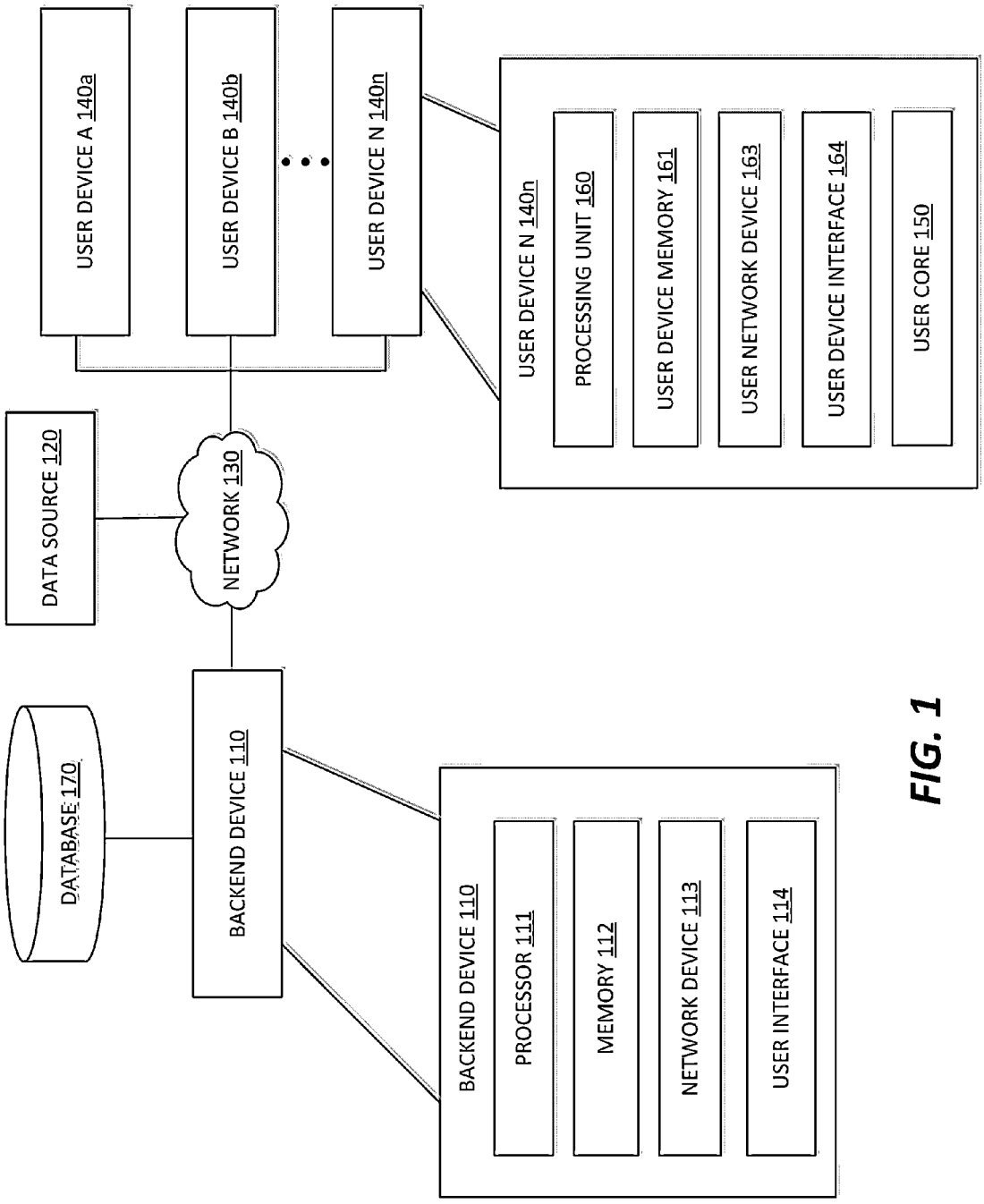

USER DEVICE A 140a
USER DEVICE B 140b
USER DEVICE N 140n
USER DEVICE N 140n
PROCESSING UNIT 160
USER DEVICE MEMORY 161
USER NETWORK DEVICE 163
USER DEVICE INTERFACE 164
USER CORE 150
DATA SOURCE 120
NETWORK 130
DATABASE 170
BACKEND DEVICE 110
BACKEND DEVICE 110
PROCESSOR 111
MEMORY 112
NETWORK DEVICE 113
USER INTERFACE 114

FIG. 1

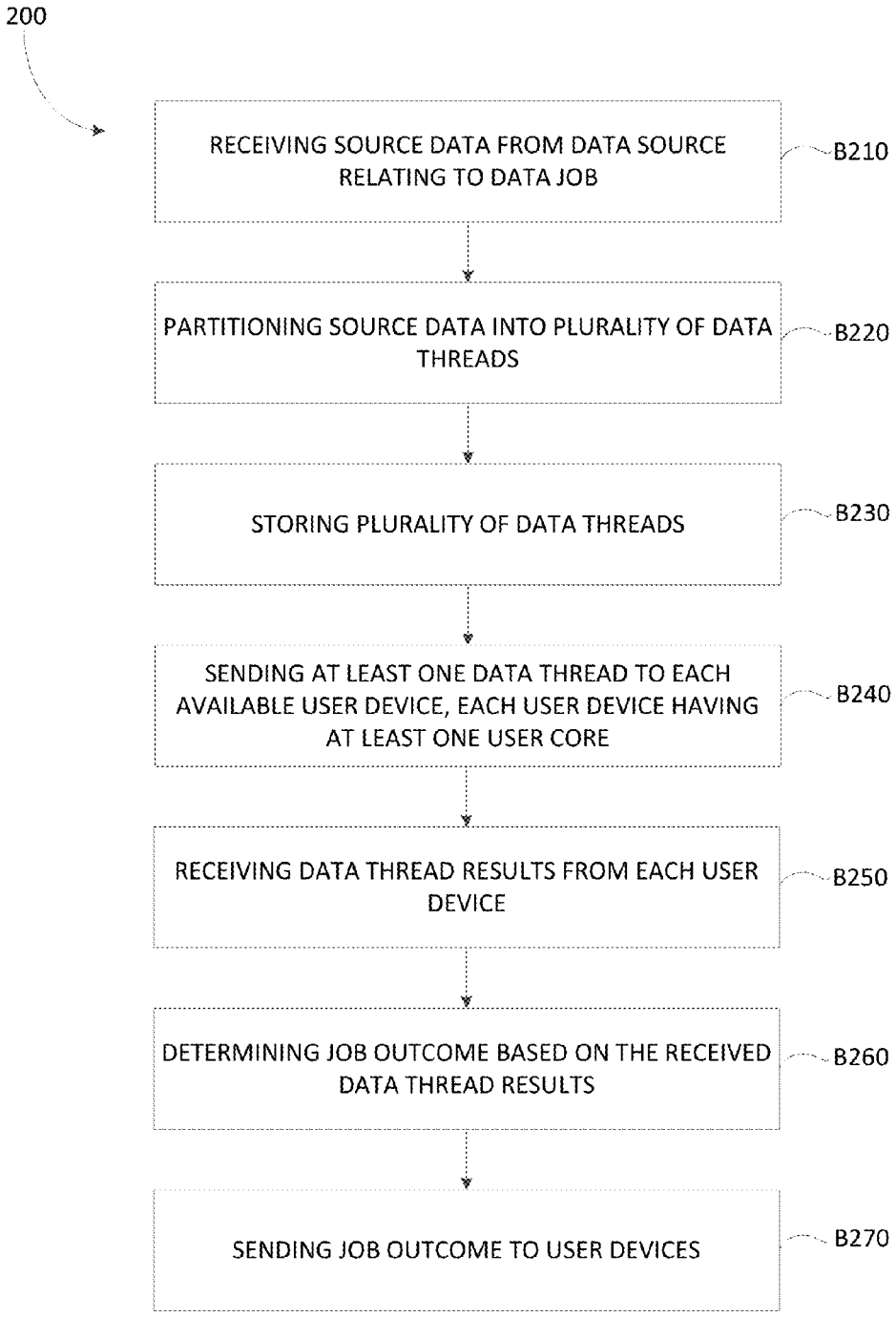

200
RECEIVING SOURCE DATA FROM DATA SOURCE RELATING TO DATA JOB
B210
PARTITIONING SOURCE DATA INTO PLURALITY OF DATA THREADS
B220
STORING PLURALITY OF DATA THREADS
B230
SENDING AT LEAST ONE DATA THREAD TO EACH AVAILABLE USER DEVICE, EACH USER DEVICE HAVING AT LEAST ONE USER CORE
B240
RECEIVING DATA THREAD RESULTS FROM EACH USER DEVICE
B250
DETERMINING JOB OUTCOME BASED ON THE RECEIVED DATA THREAD RESULTS
B260
SENDING JOB OUTCOME TO USER DEVICES
B270

*FIG. 2*

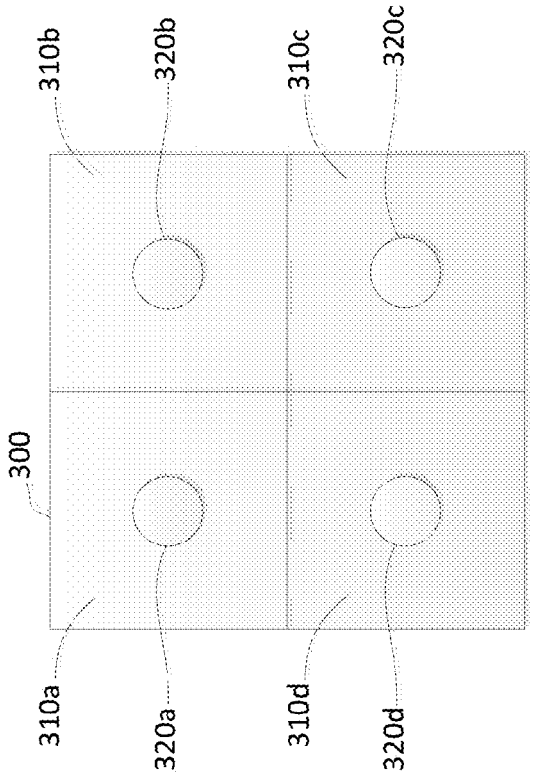

310b
320b
310c
320c
300
310a
320a
310d
320d

FIG. 3B

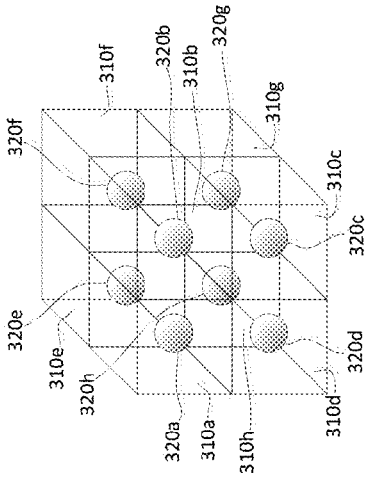

310f
320b
310b
320g
310g
320f
310c
320c
320e
310e
320h
320d
310d
320a
310a
310h

FIG. 3A

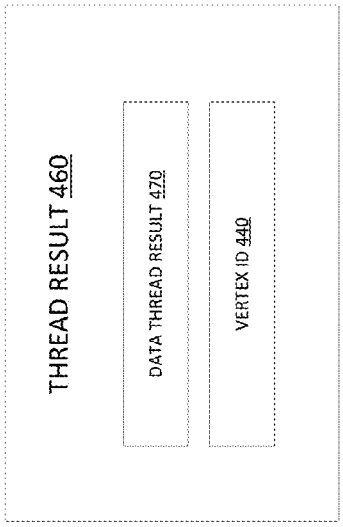

THREAD RESULT 460
DATA THREAD RESULT 470
VERTEX ID 440

FIG. 4B

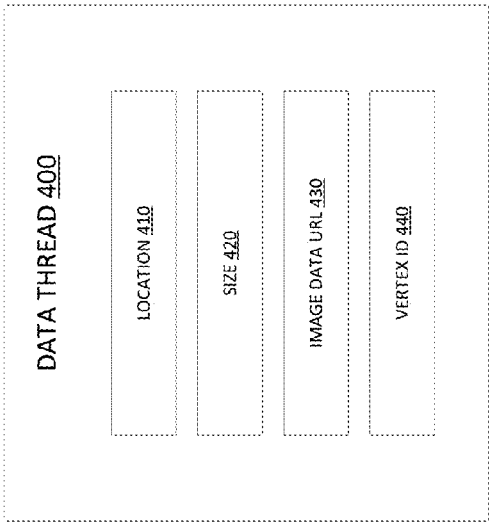

DATA THREAD 400
LOCATION 410
SIZE 420
IMAGE DATA URL 430
VERTEX ID 440

FIG. 4A

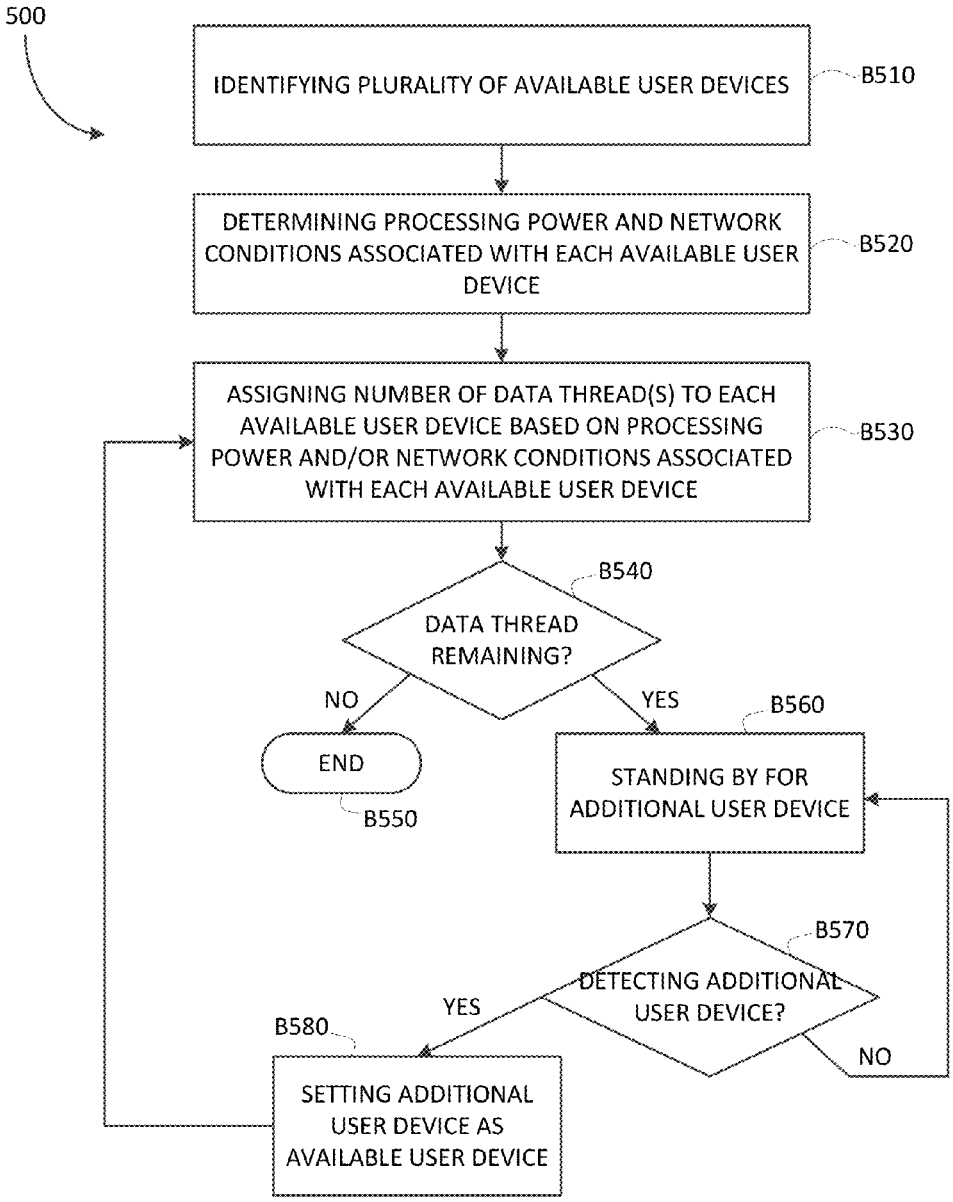

500
IDENTIFYING PLURALITY OF AVAILABLE USER DEVICES
B510
DETERMINING PROCESSING POWER AND NETWORK CONDITIONS ASSOCIATED WITH EACH AVAILABLE USER DEVICE
B520
ASSIGNING NUMBER OF DATA THREAD(S) TO EACH AVAILABLE USER DEVICE BASED ON PROCESSING POWER AND/OR NETWORK CONDITIONS ASSOCIATED WITH EACH AVAILABLE USER DEVICE
B530
B540
DATA THREAD REMAINING?
NO
YES
END
B550
B560
STANDING BY FOR ADDITIONAL USER DEVICE
B570
DETECTING ADDITIONAL USER DEVICE?
YES
NO
B580
SETTING ADDITIONAL USER DEVICE AS AVAILABLE USER DEVICE

*FIG. 5*

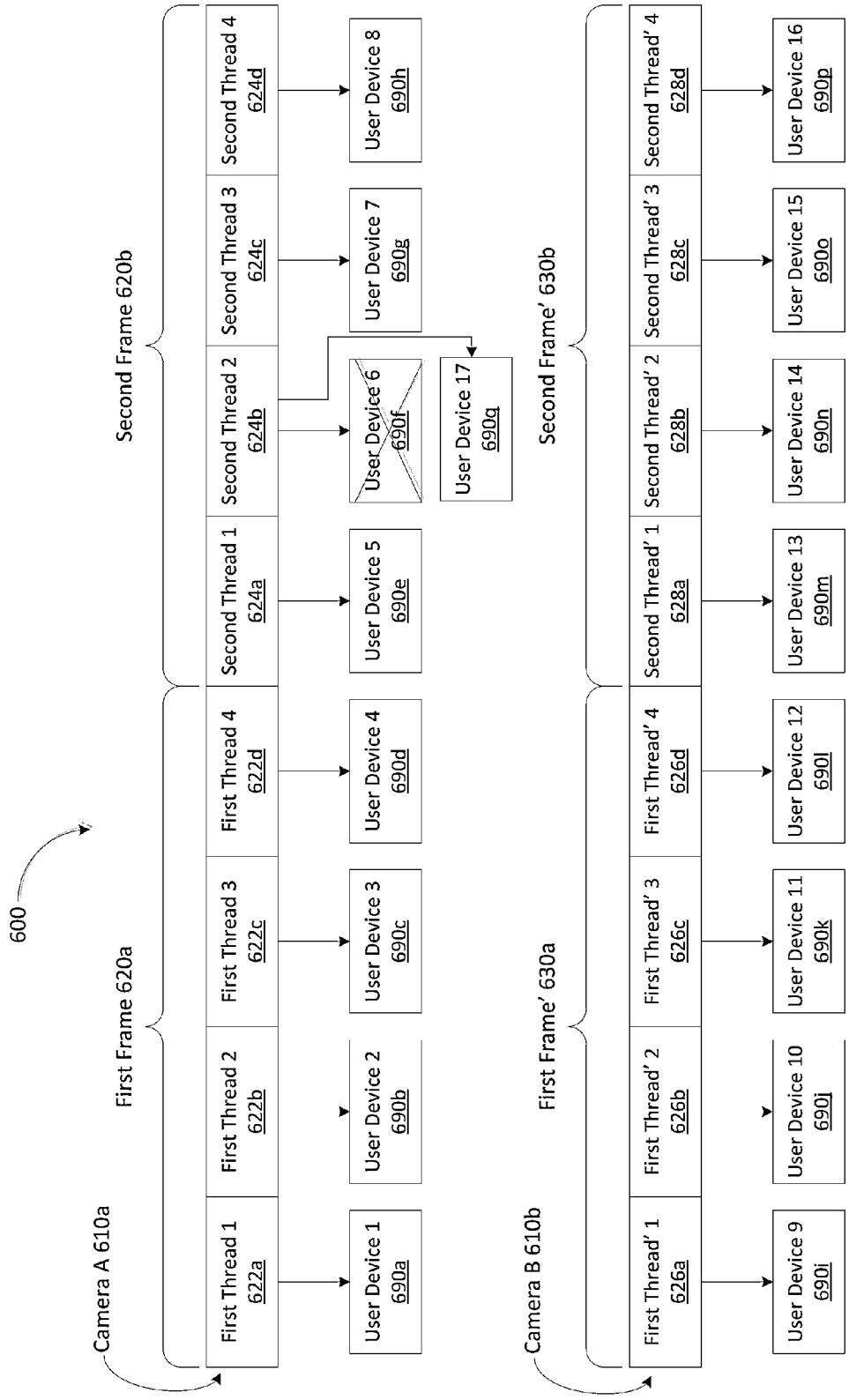
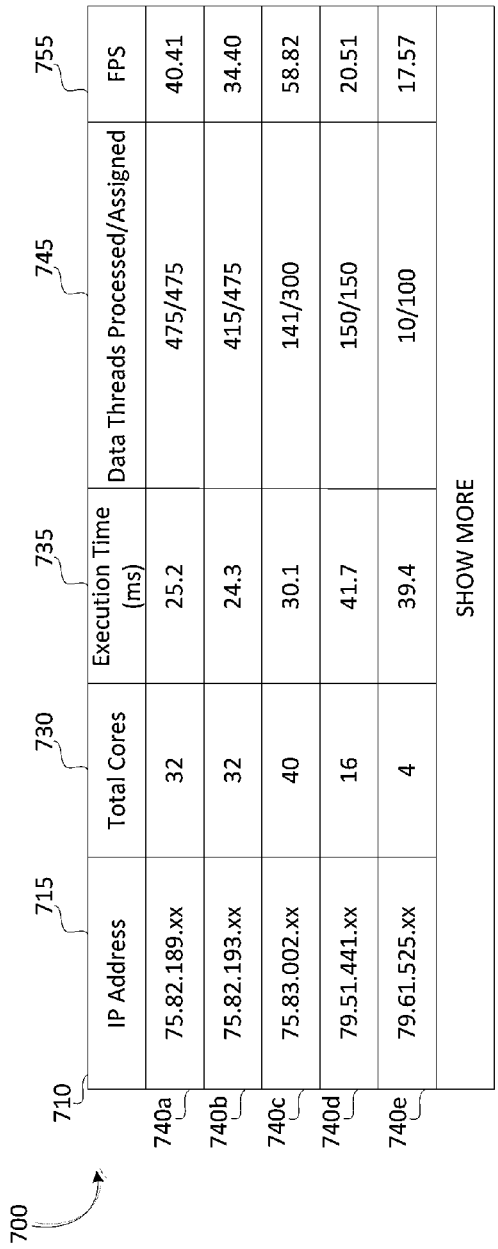

600
Camera A 610a
First Frame 620a
Second Frame 620b
First Thread 1 622a
First Thread 2 622b
First Thread 3 622c
First Thread 4 622d
Second Thread 1 624a
Second Thread 2 624b
Second Thread 3 624c
Second Thread 4 624d
User Device 1 690a
User Device 2 690b
User Device 3 690c
User Device 4 690d
User Device 5 690e
User Device 6 690f
User Device 7 690g
User Device 8 690h
User Device 17 690q
Camera B 610b
First Frame' 630a
Second Frame' 630b
First Thread' 1 626a
First Thread' 2 626b
First Thread' 3 626c
First Thread' 4 626d
Second Thread' 1 628a
Second Thread' 2 628b
Second Thread' 3 628c
Second Thread' 4 628d
User Device 9 690i
User Device 10 690j
User Device 11 690k
User Device 12 690l
User Device 13 690m
User Device 14 690n
User Device 15 690o
User Device 16 690p

FIG. 6


700
710
715
730
735
745
755
IP Address
Total Cores
Execution Time (ms)
Data Threads Processed/Assigned
FPS
740a
75.82.189.xx
32
25.2
475/475
40.41
740b
75.82.193.xx
32
24.3
415/475
34.40
740c
75.83.002.xx
40
30.1
141/300
58.82
740d
79.51.441.xx
16
41.7
150/150
20.51
740e
79.61.525.xx
4
39.4
10/100
17.57
SHOW MORE

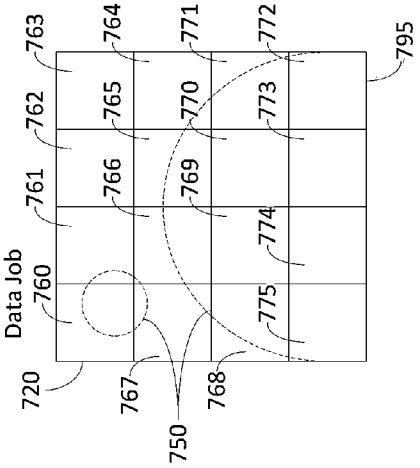

Data Job
720
750
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
795

FIG. 7

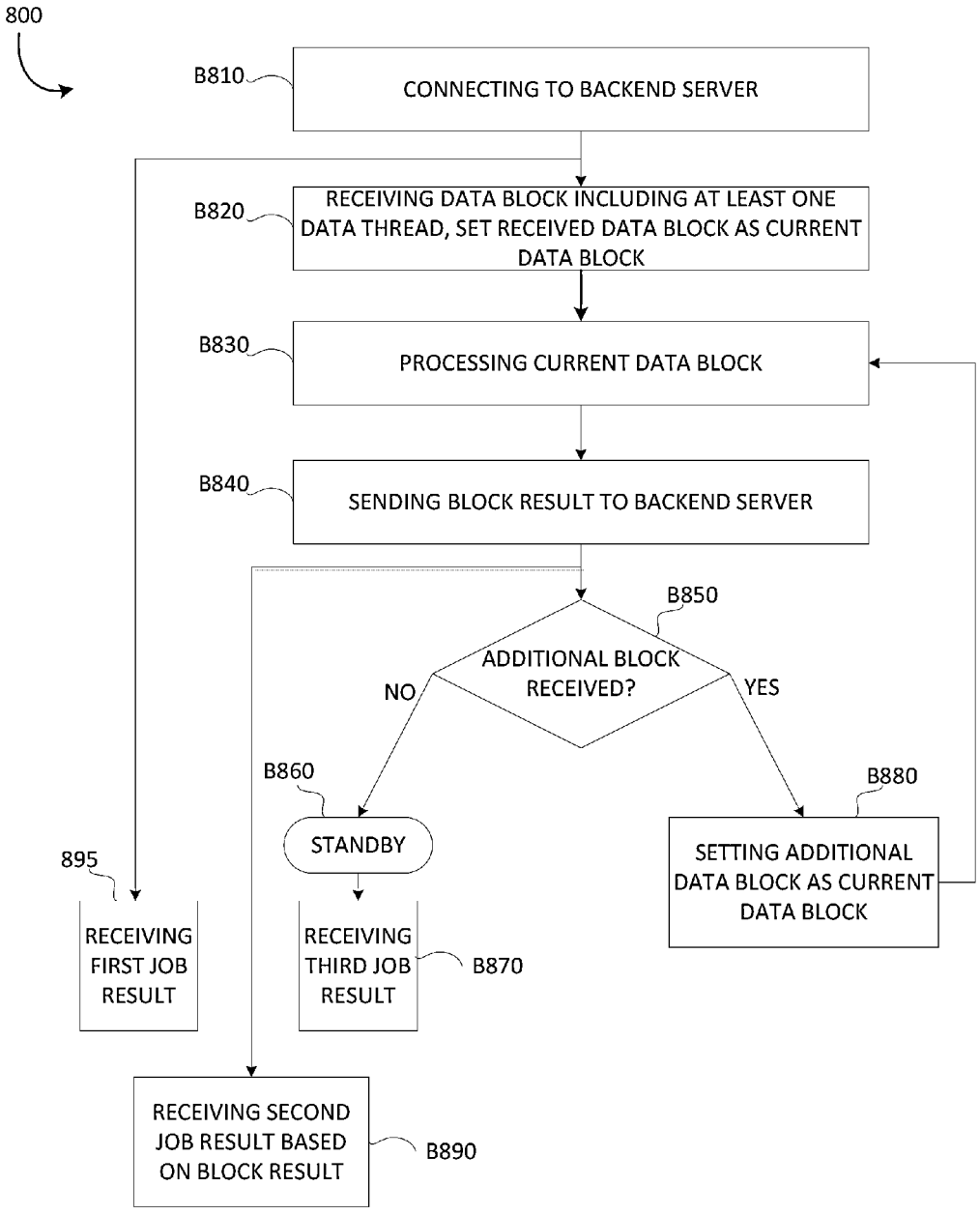

800
B810
CONNECTING TO BACKEND SERVER
B820
RECEIVING DATA BLOCK INCLUDING AT LEAST ONE DATA THREAD, SET RECEIVED DATA BLOCK AS CURRENT DATA BLOCK
B830
PROCESSING CURRENT DATA BLOCK
B840
SENDING BLOCK RESULT TO BACKEND SERVER
B850
ADDITIONAL BLOCK RECEIVED?
NO
YES
B860
STANDBY
B880
SETTING ADDITIONAL DATA BLOCK AS CURRENT DATA BLOCK
895
RECEIVING FIRST JOB RESULT
RECEIVING THIRD JOB RESULT
B870
RECEIVING SECOND JOB RESULT BASED ON BLOCK RESULT
B890

*FIG. 8*

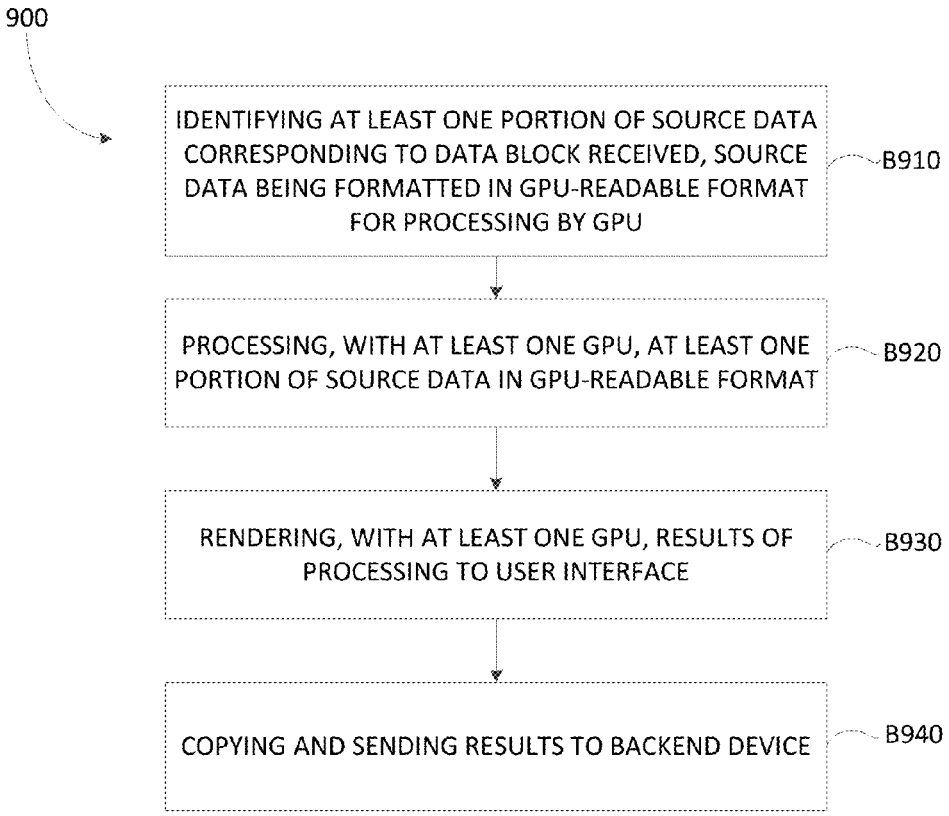

900
IDENTIFYING AT LEAST ONE PORTION OF SOURCE DATA CORRESPONDING TO DATA BLOCK RECEIVED, SOURCE DATA BEING FORMATTED IN GPU-READABLE FORMAT FOR PROCESSING BY GPU
B910
PROCESSING, WITH AT LEAST ONE GPU, AT LEAST ONE PORTION OF SOURCE DATA IN GPU-READABLE FORMAT
B920
RENDERING, WITH AT LEAST ONE GPU, RESULTS OF PROCESSING TO USER INTERFACE
B930
COPYING AND SENDING RESULTS TO BACKEND DEVICE
B940

*FIG. 9*

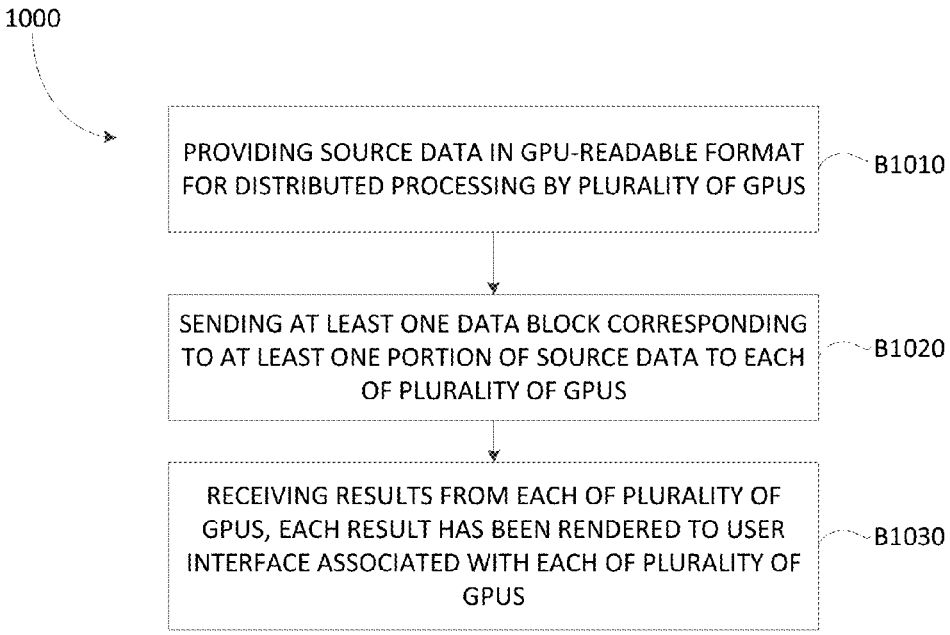

1000
PROVIDING SOURCE DATA IN GPU-READABLE FORMAT FOR DISTRIBUTED PROCESSING BY PLURALITY OF GPUS
B1010
SENDING AT LEAST ONE DATA BLOCK CORRESPONDING TO AT LEAST ONE PORTION OF SOURCE DATA TO EACH OF PLURALITY OF GPUS
B1020
RECEIVING RESULTS FROM EACH OF PLURALITY OF GPUS, EACH RESULT HAS BEEN RENDERED TO USER INTERFACE ASSOCIATED WITH EACH OF PLURALITY OF GPUS
B1030

*FIG. 10*

# SYSTEMS AND METHODS FOR SCALABLE ASYNCHRONOUS COMPUTING FRAMEWORK

## CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

This application claims priority from Provisional Application No. 61/952,055, filed Mar. 12, 2014, incorporated herein by reference in its entirety.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

Embodiments relate generally to large scale distributed computing frameworks, and more specifically, to scalable asynchronous computing frameworks using idle cores available within a network.

2. Background

Various distributed computing frameworks have been developed to perform certain complex (large-scale) computing tasks. Such distributed computing frameworks harness the processing power of a large number of cores to process complex computing tasks, which can require a tremendous amount of processing power. In particular, the complex computing tasks can be distributed to a plurality of cores for processing.

While distributed computing frameworks have been employed for certain complex computing tasks, the distributed computing frameworks can encounter capacity issues when the computing tasks are extremely complex. Given that a data processing center (e.g., Google Brain) may include a limited number of cores (e.g., 16,000 cores), the total processing power of the distributed computing framework is limited to the number of cores supported by the data processing center.

## SUMMARY OF THE DISCLOSURE

Embodiments described herein relate to distributed data processing using distributed computing frameworks. The distributed computing framework may include a backend device (e.g., a centralized server) provided to partition a computing task into a plurality of blocks (e.g., smaller concrete tasks). The backend device may distribute each of the blocks to one of a group of user devices via a network. The backend device may distribute the blocks based on processing power and network conditions associated with each of the user devices.

The distributed computing frameworks may be implemented to solve numerous computing tasks requiring tremendous processing power. In non-limiting embodiments, the distributed computing frameworks may be implemented for 3-dimensional space imaging, processing, and displaying processes. In particular, a target (3-dimensional) space is partitioned to include a plurality of vertices. Data (e.g., image data, video data, and/or the like) relating to the target space is captured by source devices (e.g., cameras). Each image or frame of a video may include a plurality of pixels, each pixel may be associated with one of the plurality of vertices. Data threads (one or more of which may form a block) may be generated by the backend device for distribution among various the user devices, where each data thread may correspond to data (e.g., pixel data) related to a vertex.

Each user device may compute a data result (e.g., a weighting value) of the data thread(s) assigned to the user device and transmit the data result back to the backend device. The backend device may determine a job outcome based on the plurality of data results received from the user devices. The backend device can, then, store the job outcome for future or real-time displaying (when the job outcome corresponds to processed image/video) on user devices. In some embodiments, the backend device may not be capable of displaying the data. The backend device may maintain the processing scheduling and data locations. Such data may be stored locally to the backend device or in a remote data storage (e.g., in another node within the network).

In some embodiments, the backend device may send the job outcome to at least some of the user devices for consumption. In other embodiments, the job outcome may not be sent to the user devices. The entities associated with the backend device or a third party may consume the job outcome. In these case, the user devices (or other nodes within the network) may not receive partial or complete job outcomes. In particular embodiments, the user devices may display a 3-dimensional projection (in the form of a video) of the target space based on the job outcome relating to the colors, textures, frequency transforms, wavelet transforms, averages, standard deviations of the vertices.

In some embodiments, the count of user devices and the data processing required to process the source data may be dynamic (e.g., change over time). Thus, the distributed computing framework may increase in scale as more user devices become available, vice versa. In various embodiments, when a threshold minimum number of user devices is not achieved for processing a given computing task in real time, dedicated user devices may be added for competing the computing tasks.

A method for processing data, the method includes, but not limited to: receiving, by a backend device, source data; partitioning, by the backend device, the source data into a plurality of data threads; sending, by the backend device, at least one of the plurality of data threads to each of a plurality of user devices; and determining, by the backend device, a job outcome for the source data based on a plurality of data thread results, each of the plurality of data thread results is determined by one of the plurality of user devices based on the at least one of the plurality of data threads.

In some embodiments, the source data is video data; and the data job includes image processing for a frame of the video data.

According to some embodiments, partitioning of the source data into the plurality of data threads includes partitioning the frame into a plurality of areas based on metadata associated with the frame and the plurality of areas, each of the plurality of areas corresponds to one of the plurality of data threads.

In some embodiments, the partitioning of the source data into the plurality of data threads includes partitioning the source data based on pixels of the source data.

According to various embodiments, the frame is an image of a target space.

In some embodiments, the target space includes of a plurality of vertices; and each of the plurality of vertices corresponds to a 3-dimensional portion of the target space.

In some embodiments, each of the plurality of data threads is associated with at least one of the plurality of vertices; and each of the plurality of data threads corresponds to an area of the frame.

In some embodiments, each of the data thread results is determined by determining a weighting value associated with at least one display characteristics associated with the area of the frame.

In some embodiments, the display characteristics includes at least a color associated with the area of the frame.

In multiple embodiments, the frame captures at least some of the plurality of vertices.

In various embodiments, the user device displays a 3-dimensional projection of the target space based on the job outcome.

According to some embodiments, determining the job outcome includes: receiving, by the backend device, the plurality of data thread results from the plurality of user devices; and determining the job outcome for the data job based on the received plurality of data thread results.

In some embodiments, sending the at least one of the plurality of data threads includes: determining at least one of processing power and network conditions for each of the plurality of user devices; and assigning each of the plurality of user devices at least one of the plurality of data threads based on at least one of the processing power and the network conditions.

In some embodiments, the method of claim further comprises formatting the source data into graphic processing unit (GPU)-compatible format, wherein each of the plurality of data thread results is determined by at least one GPU associated with each of the plurality of user devices.

In some embodiments, the GPU-compatible format is associated with shader language.

In various embodiments, the source data is formatted into at least one of the following elements: geometry, vertices, textures, normals, and code for the shader language.

In some embodiments, the data thread results are determined by rendering the data thread results to a display screen of the user devices; and copying the data thread results rendered to the display screen.

According to some embodiments, the method further comprises receiving, by the backend device, the plurality of data thread results after the plurality of data thread results have been rendered to the display screen associated with each of the user devices.

An apparatus for processing data is described with respect to various embodiments, the apparatus including, but not limited to: a backend device, the backend device is configured to: receive source data; partition the source data into a plurality of data threads; send at least one of the plurality of data threads to each of a plurality of user devices; determine a job outcome for the source data based on a plurality of data thread results, each of the plurality of data thread results is determined by one of the plurality of user devices based on the at least one of the plurality of data threads; and send the job outcome to at least one of the plurality of user devices.

Various embodiments are directed to a non-transitory computer-readable storage medium storing program instructions that, when executed, causes a processor to: receive source data; partition the source data into a plurality of data threads; send at least one of the plurality of data threads to each of a plurality of user devices; determine a job outcome for the source data based on a plurality of data thread results, each of the plurality of data thread results is determined by one of the plurality of user devices based on the at least one of the plurality of data threads; and send the job outcome to at least one of the plurality of user devices.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram illustrating an example of a distributed computing framework according to various embodiments.

FIG. **2** is a process flow chart illustrating an example of a distributed data processing method according to various embodiments.

FIG. **3**A is a schematic block diagram illustrating a perspective view of a target space according to various embodiments.

FIG. **3**B is a schematic block diagram illustrating a frontal view of the target space according to some embodiments.

FIG. **4**A is a schematic block diagram illustrating an example of a data thread according to various embodiments.

FIG. **4**B is a schematic block diagram illustrating an example of a thread result according to various embodiments.

FIG. **5** is a process flowchart illustrating an example of data thread assignment method according to various embodiments.

FIG. **6** is a schematic block diagram illustrating an example of data thread assignment and reassignment diagram according to various embodiments.

FIG. **7** is a screen illustrating an example of a management interface in some embodiments.

FIG. **8** is a process flowchart illustrating an example of a data processing method according to various embodiments.

FIG. **9** is a process flow chart illustrating an example of a GPU-oriented distributed data processing method according to various embodiments.

FIG. **10** is a process flow chart illustrating another example of a GPU-oriented distributed data processing method according to various embodiments.

## DETAILED DESCRIPTION

In the following description of various embodiments, reference is made to the accompanying drawings which form a part hereof and in which are shown by way of illustration specific embodiments in which the invention may be practiced. It is to be understood that other embodiments may be utilized, and structural changes may be made without departing from the scope of the various embodiments disclosed in the present disclosure.

As referred to herein, a "user core" may be at least one data processing unit such as, but not limited to, a microprocessor, a central data processing unit, a graphics processing unit (GPU), other types of processors, a combination thereof, or the like. In particular embodiments, a user core may be a GPU core directly assessable via a browser application without loading additional software programs or plug-ins. A "user device" may be any mobile or non-mobile computing device connected to a network (e.g., any public or private network). In some embodiments, the user device may access services provided by a backend device. The services may include, but not limited to, data transfer services, video streaming services, a combination thereof, and/or the like. Each user device may include one or more user cores for processing tasks of the user device.

A "data thread" may refer to a unit of data assigned to be processed by a user core. The data threads may be selected and assigned to a particular user core (or user device) by the backend device. In some non-limiting examples, the data thread may include a portion of an image (e.g., a fraction of a pixel, pixel(s), macroblock(s), and the like), chunks of a video, abstract data points arranged in video-like streams, metadata corresponding therewith, and/or the like. A "data block" may be a unit of data including at least one data thread. A "data job" may be any coherent computing tasks that can be segmented into a plurality of data threads/blocks for processing by the user cores. For example, a data job may be a processing task for processing at least one pixel, macroblock, frame of video data, 3-dimensional projections, filtering images, object identification for images, and/or the like.

As shown in a non-limiting example, a data job may be processing an image having a size of 1920p by 1080p. A data block may be an area on the image having a size of 128p by 128p. And within the data block, each pixel may be associated with a data thread. Thus, the data job of processing the image may be divided into 125 processing blocks, where each of the data blocks may be processed in a single frame on a single user device in the manner described (Each user device may process anywhere between 5 frames to more than 120 frames per second of any data available in any processing task it is subscribed to). Subscription to processing data jobs may be provided (e.g., hardcoded) into a website, which may include many user devices being connected to it (a lot of web traffic).

Embodiments of the current disclosure relate to systems and methods for enabling scalable distributed computing frameworks using web cores. Breakthroughs in bandwidth and web technologies allow asynchronous parallel processing framework scalable across user cores within a network. The user cores may be components of user devices, which may be operated by users to access services (e.g., web services such as video streaming services) provided within the network. Therefore, the processing power of the distributed computing framework increases with the number of user devices connected to the network (using the services provided within the network). In various embodiments, the number of user cores may be in the millions.

Implementations of the distributed computing framework include, but not limited to, large-scale image processing, web rendering, 3-dimensional WebGL rendering, deep learning neural network, image recognition, image filtering, and other suitable users described herein. In specific implementations, the distributed computing framework as described herein may be capable of processing data (e.g., video/image data) in real time, such as to provide real-time services (e.g., streaming services). For example, the user device (e.g., through the user cores) may be configured to process a portion of data used to provide the real-time streaming services. The processed data (e.g., the job outcome) may be received by the user device for providing the real-time services as described. One of ordinary skill in the art appreciates that the job outcome may not be required to be sent to the user device. The user device may be compensated in other ways such as, but not limited to, monetary compensation, services, a combination thereof, and/or the like.

In various embodiments, the processing power of each user device depends on the total processing power of the user core(s), the current processing power of the user core(s), network bandwidth status, a combination thereof, and/or the like. In typical embodiments, the distributed computing frameworks may require a small portion of the user core's processing power (e.g., the total processing power or the current processing power) such that the distributed processes assigned to the particular user device does not interfere substantially with the ordinary processes of the user core. In often cases, the users of the user devices would not be able to notice that the distributed processes are executed on the user devices.

FIG. **1** is a schematic block diagram illustrating an example of a distributed computing framework **100** according to various embodiments. Referring to FIG. **1**, the distributed computing framework **100** may include at least a backend device **110**, a data source **120**, a plurality of user devices (e.g., user device A **140***a*, user device B **140***b*, . . . , user device N **140***n*, and the like).

In some embodiments, a network **130** may allow data transfer between the backend device **110** and the user devices **140***a*-**140***n*. In further embodiments, the network **130** may also allow data transfer between the data source **120** and the backend device **110**. In still further embodiments, the network **130** may enable data transfer between the database **170** and the backend device **110**. The user devices **140***a*-**140***n* may be connected to each other through the network **130**. The network **130** may be a wide area communication network, such as, but not limited to, the Internet, or one or more Intranets, local area networks (LANs), ethernet networks, metropolitan area networks (MANs), a wide area network (WAN), combinations thereof, and/or the like. In particular embodiments, the network **130** may represent one or more secure networks configured with suitable security features, such as, but not limited to firewalls, encryption, or other software or hardware configurations that inhibits access to network communications by unauthorized personnel or entities. The data transmittable over the network **130** may be encrypted and decrypted within shader language on user cores **150** of the user devices **140***a*-**140***n* using per frame keys, further securing the data.

The data source **120** may be connected to the user devices **140***a*-**140***n* (e.g., via the network **130** or otherwise) for providing source data to be processed by the user devices **140***a*-**140***n* of the distributed computing framework **100**. For example, the data source **120** may include any suitable sources or devices for outputting unprocessed data such as, but not limited to, image/video data, application data, and/or the like. In particular embodiments, the data source **120** may include at least one camera for capturing video, image, and/or audio data. Other data sources include, but are not limited to, currency exchange rates, weather sensor data, genetic material sequencing, a combination thereof, and/or the like. The data source **120** may include a database/server for storing captured output data (e.g., the actual source data).

In some embodiments, the data sources **120** may be connected to the backend device **110** (e.g., via the network). The backend device **110** may generate metadata based on the actual data outputted by the data source **120** (and stored in the database/server associated with the data source **120**). The backend device **110** may transmit metadata (e.g., indicating particularly the partitioned data blocks/treads) to the user devices **140***a*-**140***n*. The user devices **140***a*-**140***n* may retrieve the actual data from the data source **120** (e.g., from the server/database associated with the data source) for processing as described herein.

In other embodiments, the data source **120** may include at least one of the user devices **140***a*-**140***n* having any suitable types of image/video/audio capturing capabilities (e.g., smartphone cameras). In such embodiments, the at least one of the user devices **140***a*-**140***n* may consume its own output for processing in the manner described without retrieving the actual data from the remote data source **120**. Whereas the at least one of the user devices **140***a*-**140***n* does not consume the whole output, the backend device **110** may generate metadata such that other user devices may retrieve at least a portion of the output from the at least one of the user devices **140***a*-**140***n* for processing.

The backend device **110** may include at least one processor **111**, memory **112** operatively coupled to the processor **111**, at least one network device **113**, at least one user interface **114**, and/or the like. In some embodiments, the backend device **110** may include a desktop computer, mainframe computer, laptop computer, pad device, smart phone device or the like, configured with hardware and software to perform operations described herein.

For example, the backend device **110** may include typical desktop PC or Apple™ computer devices, having suitable processing capabilities, memory, user interface (e.g., display

and input) capabilities, and communication capabilities, when configured with suitable application software (or other software) to perform operations described herein. Platforms suitable for implementation include Amazon/Debian Linux, HTML (e.g., HTML5), suitable browsers without plug-ins (such as java or flash), or the like. Thus, particular embodiments may be implemented, using processor devices that are often already present in many business and organization environments, by configuring such devices with suitable software processes described herein. Accordingly, such embodiments may be implemented with minimal additional hardware costs. However, other embodiments of the backend device **110** may relate to systems and process that are implemented with dedicated device hardware specifically configured for performing operations described herein.

The processor **111** may include any suitable data processing device, such as a general-purpose processor (e.g., a microprocessor), or executing the functions of the backend device **110** as described. In the alternative, the processor **111** may be any conventional processor, controller, microcontroller, or state machine. The processor **111** may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, a GPU, at least one microprocessors in conjunction with a DSP core, or any other such configuration.

The memory **112** may be operatively coupled to the processor **112** and may include any suitable device for storing software and data for controlling and use by the processor **111** to perform operations and functions described herein, including, but not limited to, random access memory (RAM), read only memory (ROM), floppy disks, hard disks, dongles or other recomp sensor board (RSB) connected memory devices, or the like.

The network device **113** may be configured for communication over the network **130**. The network device **113** may include interface software, hardware, or combinations thereof, for communication over the network **130**. The network device **113** may include hardware such as network modems, wireless receiver or transceiver electronics, and/or software that provide wired or wireless communication link with the network **130** (or with a network-connected device). In particular embodiments, the network device **113** may be coupled to the processor **111** for providing communication functions. The network device **113** may provide telephone and other communications in accordance with typical industry standards, such as, but not limited to code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), long term evolution (LTE), wireless fidelity (WiFi), frequency modulation (FM), Bluetooth (BT), near field communication (NFC), and the like.

In particular embodiments, the user interface **114** of the backend device **110** may include at least one display device. The display device may include any suitable device that provides a human-perceptible visible signal, audible signal, tactile signal, or any combination thereof, including, but not limited to a touchscreen, LCD, LED, CRT, plasma, or other suitable display screen, audio speaker or other audio generating device, combinations thereof, or the like.

In some embodiments, the user interface **114** of the backend device **110** may include at least one user input device that provides an interface for designated personnel using the backend device **110**. The user input device may include any suitable device that receives input from a user including, but not limited to one or more manual operator (such as, but not limited to a switch, button, touchscreen, knob, slider, keyboard, mouse, or the like), microphone, camera, image sensor, any types of remote connection control, or the like.

Still referring to FIG. **1**, in addition to (or as an alternative to) the memory **112**, the backend device **110** may be operatively coupled to the at least one database **170**. In some embodiments, the database **170** may be connected to the backend device **110** through the network **130**. In other embodiments, the database **170** may be connected to the backend device **110** in other suitable manners not through the network **130**. The database **170** may be capable of storing a greater amount of information and provide a greater level of security against unauthorized access to stored information than the memory **112** in the backend device **110**. The database **170** may include any suitable electronic storage device or system, including, but not limited to random access memory RAM, read only memory ROM, floppy disks, hard disks, dongles or other RSB connected memory devices, or the like.

In particular embodiments, the database **170** may be a NoSql database maintained by a redis server to control alerting user devices **140***a*-**140***n* of new data blocks/threads and prioritizing data blocks/threads. The user devices **140***a*-**140***n* may be capable to interact with the redis server to store and access data in an asynchronous manner (e.g., no bottlenecks given metadata is being maintained by the database **170** and/or the memory **112**; the actual data may be stored in the data sources **120**). The algorithms for such access may be structured such that no data hazards are present from overlaps. Atomic instructions may be included to avoid collision hazards.

The database **170** and/or the memory **112** may be configured to store source data (e.g., unprocessed data) from the data source **120**. In some embodiments, the source data may be stored in either the database **170** or the memory **112**. In other embodiments, at least a portion of the source data may be stored in one of the database **170** and the memory **112**, while a separate portion of the source data may be stored in another one of the database **170** or the memory **112**.

In further embodiments, the database **170** and/or the memory **112** may be configured to store segmented data threads to be send to the user devices **140***a*-**140***n* through the network **130**. The processor **111** may partition the source data (e.g., data job) into a plurality of data threads. Each data thread may be sent to one of the user devices **140***a*-**140***n* for processing. In various embodiments, the database **170** and/or the memory **112** may store only the metadata required to identify the source data. The source data itself may be hosted on a content delivery network (CDN) or another server/database residing within the data source **120**. The user devices **140***a*-**140***n* may pull (e.g., request from the backend device **110**) data blocks/threads as they become available in the manner described. This may be advantageous due to unequal processing time associated with each user core **150** of each of the user devices **140***a*-**140***n*. Alternatively, the backend device **110** may push the data blocks/threads to the user devices **140***a*-**140***n*. Once partitioned, the data threads may be stored and indexed within the database **170** and/or the memory **112** until the data threads are processed by one of the user devices **140***a*-**140***n*. Given that a user device referred to generally as the user device **140***n* may be unable to process the data thread for various reasons, the database **170** and/or the memory **112** may store an assigned but not yet processed data thread until the data thread has been processed. In still further embodiments, the database **170** and/or the memory **112** may store processed data thread results received from the user devices.

In some embodiments, data threads and/or data blocks may be stored as lists of data on the backend device **110**, which may take form of a NoSql server with a redis server main-

taining asynchronous communication between the user devices and the NoSql server. NoSql server may be used in some embodiments by virtue of its ability to allow fast access to flattened data structures. The backend device **110** (or at least a portion thereof) may be set up over a CDN, or data contained within the backend device **110** or the associated database **170** may be copied to other data centers spread around the world to eliminate any single points of failure. As such, persistent memory may be achieved for data processing even if a single node server containing data becomes offline. In various embodiments, each data thread/block may include only the minimum indexing information (e.g., metadata) needed for the user devices **140***a*-**140***n* to retrieve or otherwise obtain the correct data to be processed and/or output data. In addition, any other metadata/parameter necessary for processing the data thread (e.g., scripts, instructions, parameters, algorithms, location to store output data, a combination thereof, and/or the like) may be included in each data thread/block. Accordingly, the user devices **140***a*-**140***n*, upon receiving the data blocks/threads (which include the metadata pointing the location of the actual data), may retrieve or otherwise access the actual data (located at a server/database/network other than the backend device **110**, for example, at the data sources **120**) based on the metadata in the data blocks/threads.

Each of the user devices **140***a*-**140***n* (e.g., as depicted with respect to the user device n **140***n*) may include at least one processing unit **160**, user device memory **161** operatively coupled to the processing unit **160**, user network device **163**, user device interface **164**, and user core **150**. The user devices **140***a*-**140***n* may be dedicated or general user devices connected to the network **130**. In the event that a number of the general user devices do not meet a predetermined threshold for processing a certain computing task, additional dedicated user devices may be added (to meet the predetermined threshold, or beyond).

The processing unit **160** may be configured to execute general functions of the user devices **140***a*-**140***n*. The processing unit **160** may be any suitable data processing device, such as a general-purpose processor, microprocessor, GPU, or the like. In the alternative, the processing unit **160** may be any conventional processor, controller, microcontroller, or state machine. The processing unit **160** may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, at least one microprocessors in conjunction with a DSP core, or any other such configuration. In particular embodiments, the processing unit **160** may refer to the GPU of the user devices **140***a*-**140***n*. The GPU may be connected to the network **130** (e.g., the internet) via a browser without the need of plug-ins (e.g., java or flash) using simply HTML5, as enabled by improved network capabilities (e.g., network speed). As such, the processes of the processing unit **160** may not be noticeable to the user of each of the user devices **140***a*-**140***n*.

The user device memory **161** may be operatively coupled to the processing unit **160** and may include any suitable device for storing software and data for controlling and use by the processing unit **160** to perform operations and functions described herein. The user device memory **161** may be a RAM, ROM, floppy disks, hard disks, dongles or other RSB connected memory devices, or the like.

The user network device **163** may include interface software, hardware, or combinations thereof, for communication over the network **130**. The user network device **163** may include network modem, wireless receiver or transceiver electronics, and/or software that provide wired or wireless communication link with the network **130** (or with a network-connected device). In particular embodiments, the user network device **163** may be coupled to the processing unit **160** for providing communication functions. The user network device **163** may provide communications in accordance with typical industry standards, such as, but not limited to, CDMA, TDMA, FDMA, LTE, WiFi, FM, BT, NFC, and/or the like. In some embodiments, the network **130** may be the internet, as the user devices **140***a*-**140***n* may be spread out geographically using optimal bandwidth. In other embodiments, the network **130** may be a limited local network. The local network may be related to other private networks or the internet in general.

In further embodiments, each of the user devices **140***a*-**140***n* may include, additionally, plug-ins and hardware to accelerate GPU (e.g., the user core **150**) processing. The additional plug-ins may provide access to lower level optimized functions within the user devices **140***a*-**140***n*. The additional hardware may boost the performance for the user core **150**. The user devices **140***a*-**140***n* may also be head nodes of a data center, which processes the data blocks/threads sent to the user devices **140***a*-**140***n* and relays the data blocks/threads back to the user devices **140***a*-**140***n* to relay back to the backend device **110**.

In particular embodiments, the user device interface **164** of the user devices **140***a*-**140***n* may include at least one display device for displaying information (e.g., text and graphics) to the users. The display device may include any suitable device that provides a human-perceptible visible signal, audible signal, tactile signal, or any combination thereof, including, but not limited to a touchscreen, LCD, LED, CRT, plasma, or other suitable display screen, audio speaker or other audio generating device, combinations thereof, or the like.

In some embodiments, the user device interface **164** of the user devices **140***a*-**140***n* may include at least one user input device that provides an interface for accepting inputs of the users. The user input device may include any suitable device that receives input from a user including, but not limited to one or more manual operator (such as, but not limited to a switch, button, touchscreen, knob, slider, keyboard, mouse, or the like), microphone, camera, image sensor, and/or the like.

The user core **150** may be configured to execute data thread processing functions of the user devices **140***a*-**140***n* as described. The user core **150** may be the same as the processing unit **160** in some embodiments. In other embodiments, the user core **150** may be a processing device separate from the processing unit **160**. The user core **150** may be any suitable data processing device for processing data threads, such as at least one general-purpose processor, microprocessor, GPU, or the like. In the alternative, the user core **150** may be any conventional processor, controller, microcontroller, or state machine. The user core **150** may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, at least one microprocessors in conjunction with a DSP core, or any other such configuration.

In particular embodiments, each of the user devices **140***a*-**140***n* may be any wired or wireless computing systems or devices. In some embodiments, the user devices **140***a*-**140***n* may be a desktop computer, mainframe computer, laptop computer, pad device, or the like, configured with hardware and software to perform operations described herein. For example, each of the user devices **140***a*-**140***n* may include typical desktop PC or Apple™ computer devices, having suitable processing capabilities, memory, user interface (e.g., display and input) capabilities, and communication capabilities, when configured with suitable application software (or

other software) to perform operations described herein. In other embodiments, the user devices **140***a*-**140***n* may include a mobile smart phone (such as, but not limited to an iPhone™, an Android™ phone, or the like) or other mobile phone with suitable processing capabilities. Typical modern mobile phone devices include telephone communication electronics as well as some processor electronics, one or more display devices and a keypad and/or other user input device, such as, but not limited to described above. Particular embodiments employ mobile phones, commonly referred to as smart phones, that have relatively advanced processing, input and display capabilities in addition to telephone communication capabilities. However, the user devices **140***a*-**140***n*, in further embodiments of the present invention, may include any suitable type of mobile phone and/or other type of portable electronic communication device, such as, but not limited to, an electronic smart pad device (such as, but not limited to an iPad™), a portable laptop computer, or the like. Mobile GPU processing through native libraries as well as non-mobile GPU may be implemented to communicate on the same asynchronous network **130**.

In some embodiments, the functions performed by the user devices **140***a*-**140***n* can be implemented with minimal additional hardware costs by utilizing existing hardware. In other embodiments, systems and processes described herein can be implemented with dedicated device hardware specifically configured for performing operations described herein. Hardware and/or software for the functions may be incorporated in the user devices **140***a*-**140***n* during manufacture of the user devices **140***a*-**140***n*, for example, as part of the original manufacturer's configuration. Such hardware and/or software may also be added to the user devices **140***a*-**140***n*, after original manufacture (e.g., installing one or more software applications onto the user devices **140***a*-**140***n*).

FIG. **2** is a process flow chart illustrating an example of a distributed data processing method **200** according to various embodiments. Referring to FIGS. **1**-**2**, the distributed data processing method **200** may be implemented with the distributed computing framework **100**. In a non-limiting example, the distributed data processing method **200** may be implemented for 3-dimensional real-time streaming systems and methods implementing display threshold techniques described herein.

In general terms, such 3-dimensional real-time streaming systems and methods may refer to the backend device **110** being configured to partition the 3-dimensional graphic construction process into smaller chunks (e.g., data threads) for processing by the plurality user devices **140***a*-**140***n* (e.g., by the user cores **150**). The backend device **110** may then receive the results (e.g., data thread results) for each of the smaller chunks from the user devices **140***a*-**140***n* and compute the 3-dimensional re-construction data from the data thread results. Once computed, 3-dimensional re-construction data may be transmitted to each of the user devices **140***a*-**140***n* for rendering 3-dimensional videos. It should be noted by one of ordinary skill in the art that the distributed data processing method **200** is applicable to other types of image data processing, and data processing in general.

First at block B**210**, the backend device **110** may receive source data from the data source **120** relating to a data job. In some embodiments, the source data may be any unprocessed data such as, but not limited to, image data, video data, audio date, application data, combination thereof, and/or the like. A data job may define a particular computing task definable within the source data. In a non-limiting example, whereas the source data is graphics (e.g., video) data, a data job may delineate the portion of the source data corresponding to a frame.

Next at block B**220**, the backend device **110** may be configured to partition the source data (e.g., each data job) into a plurality of data threads. In other words, the source data may be divided into a plurality of data jobs, and each data job may be partitioned into a plurality of data threads. Such divisions of the source data may serve to break down a complex computing task into smaller segments to be processed by the plurality of user cores **150**, thus providing finer granularity and greater processing power. In particular embodiments, a unit of source data may be stored in the backend device **110**, the database **170**, or a third-party storage device in or not in the network **130**. The partitioning of the unit of source data may include obtaining location indicators (e.g., URLs) for each discrete piece of the unit of source data. The discrete pieces (or the unit of source data itself) may not be in the data threads. However, the location indicators may be stored or transmitted as data threads. In other words, the partitioning concerns metadata instead of data in some embodiments. In other embodiments, the discrete pieces themselves are stored and transmitted as the data threads.

In a non-limiting example, a video stream (the source data) may be received as separate data jobs (e.g., separate frames, each frame is a data job). Each frame may further be divided based on vertices (e.g., data threads) for processing. A vertex may be a predetermined point within a target space (e.g., a sport stadium, and the like), where each vertex may be associated with a definable volume within the target space. Each vertex may correspond to portion of a pixel, pixel(s), or macroblock(s) as captured by a digital camera (the data source **120**). In various embodiments, a data thread may be a unit of video image/video data with respect to one vertex as captured by one camera at a single frame.

Next at block B**230**, the backend device **110** may store the plurality of data threads in the database **170**, the memory **112**, a combination thereof, and/or the like. Given that there may not be as many user cores **150** available at a given time to process each data thread, all data threads may be stored. Some data threads may be processed immediate by assigning to available user cores **150** for processing. Other unassigned data threads may be stored in the database **170** or the memory **112** until a new user core **150** becomes available (e.g., by completing data thread processing of a previous data thread or by becoming connected to the network **130**). All data threads may be stored as metadata, including input data location, scripts, instructions, parameters, algorithms, location to store output data, flags need to be set a combination thereof, and/or the like. The metadata locations may be removed as processed and outputs are stored, to optimize the periodization of new unprocessed data blocks/threads.

At block B**240**, the backend device **110** may be configured to send one of the plurality of data threads to each available user device **140***n* within the network **130**, where each available user device **140***n* may include a user core **150**. In various embodiments, the backend device **110** may identify the user devices **140***a*-**140***n* within the network **130** in the manner described. The user devices **140***n* may be deemed available when the user device **140***n* has a free user core **150** to process the data threads. Data blocks/threads may be pushed down from the backend device **110** or pulled by the user devices **140***a*-**140***n* from the backend device **110**. The backend device **110** may periodically send the data blocks/threads to the user devices **140***a*-**140***n* in a push, where each user device may receive and process the sent data blocks/threads when that user device is available. Alternatively, the user device may

store the data blocks/threads for future processing. In other embodiments, each of the user devices **140***a*-**140***n* may transmit a request to the backend device **110** (when data processing is complete) to receive a new data block/thread to process, in a pull. Pulling data blocks/threads by the user devices **140***a*-**140***n* can be cost-efficient, given that the user devices **140***a*-**140***n* may access metadata from the backend device **110** asynchronously, and that each of the user devices **140***a*-**140***n* may process at different rates. The data sent to be backend devices **140***a*-**140***n* may be based on a prioritized list of data blocks/threads in the manner described.

The backend device **110** may assign each available user device **140***n* a data thread based on the total processing power of the user core **150**, the current processing power of the user core **150**, network bandwidth status, a combination thereof, and/or the like. In some embodiments, the data thread may include embedded scripts or instructions for processing the data threads sent with the data thread to the user device. The data thread may include metadata/pointers of the scripts or instructions may be included in the data thread, such that the actual scripts or instructions may be stored in another server/database other than the backend device **110** and the database **170**. The user devices **140***a*-**140***n* may retrieve or otherwise access the actual scripts or instructions from the another server/database based on the location pointed by the metadata of the data thread. The scripts or instructions may be data thread-specific. In other embodiments, the instructions may be pre-stored in the user device memory **161** of the user devices **140***a*-**140***n*. In some cases, a decryption key may also be sent with the data blocks/threads to decrypt the corresponding data blocks/threads with user core **150** (GPU) memory. The user core **150** may then process the data blocks/threads with the user core **150** and re-encrypt the block results for private or DRM-capable processing.

Next at block B**250**, the backend device **110** may receive data thread results from the available user devices **140***a*-**140***n* via the network **130**. Each data thread result may correspond to a sent data thread. After the available user devices **140***a*-**140***n* process the sent data threads (e.g., determining the data thread results), the data thread results may be sent to the backend device **110** by the user devices **140***a*-**140***n*. In particular embodiments, one of the user devices **140***a*-**140***n* may process the image/video data related to a particular vertex for a data thread result (e.g., a weighting value) corresponding to that vertex in the manner described.

Next at block B**260**, the backend device **110** may determine a job outcome for each data job based on the received data thread results. For example, the backend device **110** may store all data thread results corresponding to data threads making up a data job as they are received. Given network characteristics and processing power associated with each user core **150**, data thread results making up a data job may be received at different times. Once all data thread results are received, the backend device **110** may determine the job outcome for the entire data job. In other embodiments, the user devices **140***a*-**140***n* may determine the job outcome in pieces when a large output is anticipated. The pieces of the job outcome may then be compacted into manageable streams. In specific embodiments, weighting values for a vertex (e.g., as determined from various cameras and various frames) may be gathered and computed to determine display confidence level with respect to the color corresponding to the particular vertex.

Next at block B**270**, the backend device **110** may send the job outcome to the user devices **140***a*-**140***n* for consumption. In particular embodiments, the user devices **140***a*-**140***n* may receive the weighting factors (e.g., the job outcomes) with respect to the color corresponding to a particular vertex in the target space and store them within the user device memory **161**. The user devices **140***a*-**140***n* may reconstruct the target space in 3-dimensional reconstruction processes based on the color associated with each vertex with the processing unit **160** and/or the user core **150**. Accordingly, the user devices **140***a*-**140***n* participate in the graphical processing stage by contributing at least a portion of their processing power (through user cores **150**) and consuming the end product of the graphical processing.

FIG. **3**A is a schematic block diagram illustrating a perspective view of a target space **300** according to various embodiments. FIG. **3**B is a schematic block diagram illustrating a frontal view of the target space **300**. Referring to FIGS. **1**-**3**B, the target space **300** may be partitioned into a plurality of volumes **310***a*-**310***h* (e.g., a first volume **310***a*, a second volume **310***b*, . . . , an eight volume **310***h*). Each of the volumes may be associated with a vertex. For example, the first volume **310***a* may be associated with a first vertex **320***a*, the second volume **310***b* may be associated with a second vertex **320***b*, . . . , the eight volume **310***h* may be associated with an eighth vertex **320***h*. Each of the volumes **310***a*-**310***h* may be of any suitable shape such as, but not limited to cuboids, cubes, and the like.

The volumes **310***a*-**310***h* and/or the vertices **320***a*-**320***h* may be predetermined given that the dimensions for the target space **300** may be known. In some embodiments, for a target space **300** of 60' by 30' by 10', there may be 6,000,000 vertices such as, but not limited to, the vertices **320***a*-**320***h*. A larger number of vertices in a given target space **300** may allow fine detailing of the target space **300**.

Each of the vertices **320***a*-**320***h* may correspond to a portion of a pixel (e.g., 1/16, 1/8, 1/4, 1/2, or the like), pixel(s), macroblock(s), or the like when projected and displayed in a 3-dimensional context. For example, the user device interface **164** of each of the user devices **140***a*-**140***n* may be configured to display 3-dimensional projections of the target space **300** based on the vertices **320***a*-**320***h*. Each vertex may be associated with display characteristics such as, but not limited to, colors, textures, frequency transforms, wavelet transforms, averages, standard deviations. Various embodiments described herein may refer to color as an exemplary display characteristic. One of ordinary skill in the art would know that other display characteristics as stated may also be implemented in a similar manner.

Each display characteristics may be determined based on multi-camera output. For example, multiple cameras may be positioned around the target space **300**. Given that the camera pose (position and orientation) may be known in advance, the vertices **320***a*-**320***h* captured by each camera may be determined. For example, a camera capturing the frontal view of the target space **300** may capture the frontal vertices (e.g., the first vertex **320***a*, the second vertex **320***b*, the third vertex **320***c*, and the fourth vertex **320***d*). Additional cameras may capture the back, top, bottom, and/or side views of the target space **300** along the dimensions of the target space **300**. Thus, a single vertex may be captured by multiple cameras. In particular, the cameras may capture display characteristics associated with each vertex. One display characteristic is the color associated with each vertex.

For each vertex defined within the target space **300**, a weighting value may be determined for each possible color associated with the vertex (and the associated volume). Each time a camera captures a vertex (e.g., in an image or a frame of a video) in a first color, the weighting value for the first color will increase by one. Similarly, each time a camera captures a vertex in a second color, the weighting value for the second color will increase by one. Thus, the weighting values

are determined (i.e., determining the color for the vertex as captured each of the plurality of cameras capable of capturing the vertex) for each color associated with the vertex. Higher weighting values for a particular color indicates that the vertex has been captured in that particular color by a larger number of cameras, increasing the confidence level that the vertex is associated with the particular color at a given moment in time. In some embodiments, whereas the weighting value for a color (e.g., the first color) exceeds a threshold value, then the vertex may be determined to be associated with the first color. In some embodiments, the user devices **140***a*-**140***n* may display the video projections of the target space **300** based on the color associated with each vertex. In further embodiments, additional devices that did not contribute to the data processing (e.g., not connected to the network **130** at the time of processing) may also benefit from the processes of the user devices **140***a*-**140***n* and the backend device **110**, and display the video projections of the target space **300** based on the color associated with each vertex.

Displaying the video projections of the target space **300** may be achieved by streaming the job outcome to a CDN in the form of depth videos, which scan and represent the target space **300** from the outside-in. Scanning may involve taking each pixel of the output video and projecting it into the space from each 4-5 surface of a cubic region of interest. The projected vertex value in x, y, z may be re-encoded into R, G, B to stream to the user devices. User devices may then re-interpret the data into a 3-dimensional model in real time for viewing in different perspectives, angle, and distance.

In another approach, standard deviation of all colors may be determined. The average of the colors may be chosen if the standard deviation is below a predetermined threshold. On the other hand, whereas the standard deviation of all potential colors is above a predetermined threshold, it means that the vertex projects to different colors in a substantial number of cameras (e.g., data source **120**). Thus, it is likely that the vertex may the interior of a volume in the target space **300** rather than a vertex associated with a color.

The backend device **110** may receive the source data from the cameras surrounding the target space **300**. Next, the backend device **110** may partition the source data into a plurality of data threads based on the vertices associated with the target space **300**. For example, a portion of a pixel, pixel(s), macroblock(s) of the source data corresponding to a given vertex may be identified (e.g., with respect to block B**220**) and stored together with the vertex (e.g., with respect to block B**230**). Also stored together with the vertex (as sometimes identified by a unique vertex ID) are colors identified with the vertex and the corresponding weighting values.

FIG. **4**A is a schematic block diagram illustrating an example of a data thread **400** according to various embodiments. The data thread **400** may be any data thread referred to herein. Generally, a data thread may include metadata (e.g., source data location, specific identification of portions of the source data, other suitable processing parameters, and the like) corresponding to the source data, which is stored separately from the metadata. The actual source data may be stored in the data sources **120**. Metadata may be of lesser size than actual source data itself, thus is more cost-effective to be moved from the backend device **110** to the user devices **140***a*-**140***n*. The user devices **140***a*-**140***n* themselves may retrieve or otherwise access the actual source data for processing based on the metadata stored in the data thread. Alternatively, the data thread may include the source data itself.

Specifically, FIG. **4**A illustrates the data thread **400** of an image processing context, where the source data may be images, video frames, a combination thereof, and/or the like. Referring to FIGS. **1**-**4**A, the data thread **400** may be generated by the backend device **110** (by partitioning the source data in the manner described), stored in the database **170** and/or the memory **112**, In some embodiments, the data thread **400** may include at least a location **410**, size **420**, image data URL **430**, and vertex ID **440**. The vertex ID **440** may identify a specific vertex (e.g., the first vertex **320***a*) within the target space **300**.

In various embodiments, the image data URL **430** may be an address from which the user devices **140***a*-**140***n* may access or retrieve a portion of the source data (e.g., an image, frame, and/or the like) corresponding to the data job. In particular embodiments, the image data URL **430** may be a uniform resource locator address for the image/frame (e.g., the data job) as captured by a camera. The image/frame may be stored as the source data on the database **170**, the memory **112**, or another server. The image/frame may capture a plurality of vertices of the target space **300**, including the vertex associated with the vertex ID **440**. The location **410** may be a position in the image/frame (as contained in the image data URL **430**) associated with the vertex associated with the vertex ID **440**. The location **410** may be a fraction of a pixel or at least one pixel. The size **420** refers to the size of the portion (e.g., an area) of the image/fraction associated with the vertex. In other words, the size **420** dictates the area around the location **410** that is associated with the vertex. The size **420** may be 1/16, 1/8, 1/4, 1/2, 1, 2, 3, 4 pixels (extending in any direction of the image/frame from the location **410**), and/or the like. In some embodiments, the size **420** may correspond to the volume associated with each vertex. For example, the larger the volume is, the larger it would appear on the image.

By storing the entire image remotely and sending only sufficient identification information (e.g., the location **410**, the size **420**, and the image data URL **430**) to the user devices **140***a*-**140***n* for performing data processing, bandwidth may be conserved given that the data size for transmitting image/frame data may be greater than the data size for transmitting the identification information. In other embodiments, the data thread **400** may include the particular portion of the image/frame (as would be otherwise identified by the location **410**, the size **420**, and the image URL **430**) and the vertex ID **440**.

FIG. **4**B is a schematic block diagram illustrating an example of a thread result **460** according to various embodiments. Referring to FIGS. **1**-**4**B, the thread result **460** may be generated by each of the user devices **140***a*-**140***n* and transmitted to the backend device **110**. The thread result **460** may include at least a data thread result **470** and the vertex ID **440**. The data thread result **470** may be the processed results of the data thread **400** as described. In particular embodiments, the data thread result **470** may include a color or an indicator indicating the color associated with the area of the image/frame. For example, the area may be identified by the location **410** and the size **420** of the data thread **400**. The image/frame may be contained within the image data URL **430**. The source data may be located within the network **130** or anywhere on the internet.

When each of the user devices **140***a*-**140***n* receives the data thread **400**, each of the user devices **140***a*-**140***n* may retrieve the area of the image/frame associated with the vertex by accessing the image data URL **430** and locating the area with the location **410** and the size **420** as described. Each of the user devices **140***a*-**140***n* may then determine display characteristics (e.g., color) associated with the area. The color may be transmitted together with the vertex ID **440** back to the backend device **110** in the thread result **460**. The backend device **110** may then index the data thread results **470** accord-

ing to the vertex ID **440**. The backend device **110** may increase the weighting value of the color set forth in the data thread result **470** or the vertex associated with the vertex ID **440**.

In various embodiments, a single data thread **400** may be sent to a user device **140***n* at a time. Another data thread **400** may be sent to the user device **140***n* when the previous data thread **400** has been processed (e.g., the data thread result **460** has been received by the backend device **110**). In other embodiments, a block (i.e., a unit of data including a plurality of data threads such as the data thread **400**) may be sent to the user devices **140***a*-**140***n* for distributed processing. Thus, time may be conserved when multiple data threads **400** are transmitted to the user devices **140***a*-**140***n*.

FIG. **5** is a process flowchart illustrating an example of data thread assignment method **500** according to various embodiments. In various embodiments, the data thread assignment method **500** may correspond to block B**240** of the distributed data processing method **200** of FIG. **2**.

Now referring to FIGS. **1**-**5**, first at block B**510**, the backend device **110** may identify a plurality of available user devices (e.g., the user devices **140***a*-**140***n*). In some embodiments, the available user devices may be identified when the available user devices are connected to the backend device **110** e.g., through the network. In a non-limiting example, the backend device **110** may provide a web service (e.g., in the form of a website) that the user devices **140***a*-**140***n* may access. The backend device **110** may generate a list of internet protocol (IP) addresses, where each IP address may represent at least one of the user devices **140***a*-**140***n*. In another non-limiting example, the backend device **110** may provide authentication applications such that each of the user devices **140***a*-**140***n* may be identified once authentication to the backend device **110** is successful. The database **170** and/or the memory **112** may maintain a list of user devices **140***a*-**140***n* (as identified by suitable identifiers such as the IP addresses, login credentials, and/or the like).

An identified user device is deemed to be an available user device when it is not currently processing any data threads **400** sent by the backend device **110**. Once connected to the backend device **110**, one of more of the user devices **140***a*-**140***n* may become "busy" when they are processing the data threads **400** assigned by the backend device **110**.

At block B**520**, the backend device **110** may determine, with the processor **111**, processing power and network conditions associated with each available user device. In some embodiments, the backend device **110** may determine (e.g., via scripts) or cause each available user device to determine the processing power of each available user device. The processing power may refer to the total processing power, the current available processing power (taken into account processing power consumption of processes other than data thread processing), and the like. In some embodiments, the processing power (e.g., the total processing power) may be approximated from the number of user cores **150** available to a given user device **140***n*. In a non-limiting example, an available user device may be deemed as having high processing power when it has 8 or more user cores **150** while another available user device may be deemed as having low processing power when it has 4 or less user cores **150**. In particular embodiments, the number of user core **150** may refer to a number of GPU cores.

In some embodiments, the backend device **110** may determine (e.g., via scripts) the network conditions (e.g., total network bandwidth, available bandwidth, and/or the like) associated with each of the available user device. In further embodiments, the backend device **110** may determine the network conditions associated with the backend device **110** as well.

Next at block B**530**, the backend device **110** (via the processor **111**) may assign a number of data threads for each available user device based on the processing power and/or the network conditions associated with each available device. In general terms, a number of data threads **400** assigned to a given available user device may be greater when the processing power and/or the network conditions are greater. In some embodiments, more data threads **400** may be assigned to a first available user device than to a second available user device, where the first available user device has more processing power (e.g., total processing power, current processing power, and/or the like) as compared to the second available user device. For example, 475 data threads may be assigned to an available user device with 16 user cores **150** while 200 data threads may be assigned to an available user device with 4 user cores **150**. In alternative or further embodiments, more data threads **400** may be assigned to a third available user device than to a fourth available user device, where the third available user device has improved network conditions (e.g., more bandwidth, and/or the like) as compared to the third available user device.

The number of data thread(s) assigned to an available user device may be arranged in a block. A block including at least one data thread **400** may be sent to each available user device, and the thread results **460** for each data thread **400** contained in the block may be returned (together, as a unit) to the backend device **110**.

Determining the number of data threads **400** (e.g., the size of the block) sent to an available user device at a given instance based on the processing power and the network conditions associated with the available user devices in the manner described can allow efficient data processing for solving the data job. In various embodiments, the block may require a small percentage (e.g., 0.5%, 1%, 2%, 5%, 10%, and/or the like) of the total and/or current processing power of the user cores **150** of the available user devices such that the processing of the block may appear negligible to the user of the available user devices. Accordingly, complex computing tasks such as live-streaming of 3-dimensional target space **300** may be enabled by the distributed computing framework **100**, the distributed data processing method **200**, and the related disclosure herein.

In various embodiments, the data source **120** may continuously and/or periodically feed source data to the backend device **110** for partitioning (with respect to block B**220**) and storing (with respect to block B**230**). For example, video cameras (as the data source **120**) may continuously feeding video data (as the source data) to be processed. Thus, as previous data threads **400** are processed by the available user devices, new data threads **460** may be partitioned, stored, and standing by to be processed.

Next at block B**540**, the backend device **110** may determine (with the processor **111**) whether at least one data thread **460** remains unassigned to an available user device. Given that the number of available user devices connected to the backend device **110** may fluctuate over time, all data threads **400** stored in the database **170** and/or the memory **112** at a given time may or may not be immediately assigned to an available user device. When all the stored data threads **400** are assigned at a given time, the distributed computing framework **100** may possess ample processing power (e.g., a sufficient number of user cores **150** are made available to the backend device **110**) to process the source data almost instantaneous, subject to only network and processing delays. On the other hand,

large number of data threads **400** remaining after assignment at a moment time may indicate insufficient processing power and larger processing time of the source data.

In some embodiments, the resolution of the job outcome may be adjusted based on processing power (e.g., the number of available user cores **150**). For example, when a higher number of available user cores **150** (exceeding a predetermined threshold) are connected to the network **130**, the job outcome (e.g., processed image data) may be of a higher resolution, which requires more processing power. On the other hand, when a lower number of available user cores **150** (below a predetermined threshold) are connected to the network **130**, the job outcome (e.g., processed image data) may be of a lower resolution, which requires less processing power.

Whereas there are no data threads **400** remaining unassigned, the data thread assignment method **500** may be terminated at block B**550** (B**540**:NO). In some examples, there are no data threads **400** remaining when all the outstanding partitioned (with respect to block B**220**) and stored (with respect to block B**230**) data threads **400** have been assigned to an available user device. In some embodiments, this may occur when the data source **120** is no longer receiving source data. In other embodiments, this may occur when the data source **120** has not yet transmitted new source data to the backend device **110** or when the backend device **110** has not yet partitioned or stored new data threads **400** corresponding to new source data.

In various embodiments, the backend device **110** may be configured to standby for new data threads **400** to be partitioned/stored when no data thread remains (B**540**:NO). Upon determining (e.g., with the processor **111**) that new data threads **400** are stored, the backend device **110** may assign a number of new data threads **400** for each available user device at the time based on processing power and/or network conditions associated with each available user device such as, but not limited to, described with respect to block B**530**. The data thread assignment method **500** may continue from block B**530** onward (e.g., to blocks B**530**, B**540**, B**550**, B**560**, B**570**, and/or B**580**).

Whereas there are data threads **400** remaining unassigned, the backend device **110** may standby for additional user devices at block B**560** (B**540**:YES). The standing by block B**560** may be terminated when the backend device **110** detects at least one additional user device e.g., the user device **140***a*-**140***n* at block B**570**. In some embodiments, a busy user device be detected to be an additional user device when that busy user device (e.g., a user device assigned to process a block of data thread(s)) completes processing the block and returns thread results **460** for each of the data threads **400** contained in the block. In further embodiments, a user device **140***n* that has been identified by the backend device **110** (in a manner such as, but not limited to, as described with respect to block B**510**) subsequent to the remaining data thread **400** remaining block B**540** may be deemed as an additional user device.

The backend device **110** may periodically seek to detect, with the processor **111**, whether an additional user device is present. When no additional user device has been detected, the backend device **110** may revert to the standing by at block B**560** (B**570**:NO) until at least one additional user device has been detected. Whereas the at least one additional user device has been detected in the manner described, the backend device **110** may set the detected additional user device as an available device at block B**580** (B**570**:YES). Next, the backend device **110** may assign data thread(s) **400** (remaining data thread(s) and new unprocessed data thread(s) partitioned and stored) to each available (e.g., additional) user device based on processing power and/or network conditions associated with each available user device such as, but not limited to, as described with respect to block B**530**.

FIG. **6** is a schematic block diagram illustrating an example of data thread assignment and reassignment diagram **600** according to various embodiments. In various embodiments, the data thread assignment and reassignment diagram **600** may correspond to block B**240** of the distributed data processing method **200** of FIG. **2**.

Now referring to FIGS. **1**-**6**, data sources **120** may include a first camera (e.g., camera A **610***a*) and a second camera (e.g., camera B **620***b*). Each of the camera A **610***a* and the camera B **610***b* may feed image/video data as the source data to the backend device **110** to be partitioned and stored for processing as described. For example, the camera A **610***a* may send a first frame **620***a* and a second frame **620***b* to the backend device **110**. The first frame **620***a* and the second frame **620***b* may be consecutive frames. The camera B **610***b* may send a first frame' **630***a* and a second frame' **630***b* to the backend device **110**. The first frame' **630***a* and the second frame' **630***b* may be consecutive frames.

Each of the first frame **620***a*, the second frame **620***b*, the first frame' **630***a*, the second frame' **630***b* may be divided into a plurality of data threads (such as, but not limited to, the data thread **400**) by the processor **111** of the backend device **110**. As described, each frame may include a plurality of areas. Each area may correspond to a vertex (such as, but not limited to, the vertices **320***a*-**320***g*) within a given space (such as, but not limited to, the target space **300**). For example, the first frame **620***a* may include a first thread **1 622***a*, a first thread **2 622***b*, a first thread **3 622***c*, and a first thread **4 622***d*. In various embodiments, each frame may include 400, 1,000, 5,000, 20,000, 360,000 data threads. For illustrative purposes, only 4 data threads for each frame are illustrated.

Each of the data threads (e.g., the first thread **1 622***a*-first thread **4 622***d*, second thread **1 624***a*-second thread **4 624***d*, the first thread' **1 626***a*-first thread' **4 626***d*, and second thread **1 628***a*-second thread **4 628***d*) may be assigned to an available user device as identified, for example, with respect to block B**510**. The first thread **1 622***a* may be assigned to a user device **1 690***a*, a first thread **2 622***b* may be assigned to a user device **2 690***b*, . . . , and the second thread' **4** may be assigned to a user device **16 690***p*. It should be appreciated that blocks of various sizes (e.g., containing various numbers of data threads) may be assigned to different user devices. One data thread is shown to be assigned to a disparate user device for simplicity.

Second thread **2 624***b* may be assigned (initially) to a user device **6 690***f* for processing. In some embodiments, the processing of a data thread **400** assigned to an available user device (e.g., the user device **6 690***f*) may fail for various reasons such as, but not limited to, network failure, active disconnection from the backend device **110**, processing failure, unsuccessful transmission of the data thread **400** or the result thread (e.g., the data thread result **470**), a combination thereof, and/or the like. The backend device **110** may detect such failures and reassign the second thread **2 624***b* to another user device (e.g., the user device **17 690***q*) for processing.

In some embodiments, data threads **400** corresponding to frames received prior in time for a given camera (e.g., the camera A **610***a*) may be prioritized (by the processor **111** of the backend device **110**) over frames of the same camera or another camera (e.g., camera B **610***b*) received later in time. Prioritizing one data thread **400** over another refers to the one data thread **400** being assigned an available user device while the another data thread **400** being assigned to another user device only when an additional user device is available. In

other words, when a data thread from a prior frame (e.g., the first thread **1 622***a*) and a data thread from a later frame (e.g., the second thread **1 624***a*) are standing by to be assigned to a user device, the data thread **400** from the prior frame may be assigned to an available user device first. For example, the first thread **1 622***a* (instead of the second thread **1 624***a*) may be assigned to the user device **1 690***a* when only the user device **1 690***a* is available at the time of assignment. The second thread **1 624***a* may be assigned to the user device **5 690***e* when the user device **5 690***e* becomes available at a later time.

In some embodiments, a failed data thread **400** corresponding to a frame received prior a given camera may be prioritized (by the processor **111** of the backend device **110**) over data threads corresponding to frames of a same or different camera. In particular embodiments, failed data thread **400** may be prioritized only over data threads **400** of a subsequent frame (of a same or different camera) yet to be processed.

Accordingly, multiple data threads **400** (or blocks) may be processed in parallel asynchronously over multiple user devices **140***a*-**140***n* (or user cores **150**). Each data thread **400**/block may be processed by a user device **140***n* independent of the processes of other user devices **140***a*-**140***n* for other data threads **400**/blocks. Any user device **140***n* can process any data thread **400** when the user device **140***n* becomes available for processing. It should be noted that prioritizing of data threads based on time (e.g., the sequential ordering of frames) and processing status (e.g., failed data threads may be processed first with an available user device to control stream delaying) may be implemented to optimize the process as described.

Advantages associated with the distributed data processing systems and methods also include free scaling of processing power. The processing power of the distributed data processing systems may depend on the number of user devices **140***a*-**140***n* connected to the backend device **110** (e.g., which may be an asynchronous NoSql metadata server). The processing power is scaled up when more user devices **140***a*-**140***n* are connected to the backend device **110**, vice versa.

In some embodiments, the data processing at the user device (e.g., the user devices **140***a*-**140***n*) may be executed (e.g., as trigger in a web browser) without requiring special plugins, thus simplifying the data processing. For example, each of the user devices **140***a*-**140***n* may be a HTML5 capable web client that may execute data processing in the manner described without the use of plugins. In some embodiments, all barriers to connect the user devices **140***a*-**140***n* to the backend device **110** and to retrieve unprocessed data may be eliminated. No software is required to be downloaded for processing. The data processing requires minimal processing power of the user devices **140***a*-**140***n* as compared to the total or currently available processing power. In various embodiments, the data processing of the data threads **400**/blocks has very little impact, if any, on the user experience of using the user devices **140***a*-**140***n*.

FIG. **7** is an example screen illustrating a management interface **700** in some embodiments. The management interface **700** may be displayed by the user interface **114** of the backend device **110** to designated personnel operating the backend device **110**. Through the management interface **700**, the designated personnel may monitor the distributed data process (e.g., the distributed data processing method **200** of FIG. **2**, the data thread assignment method **500** of FIG. **5**, the data processing method **800** of FIG. **8**, a combination thereof, and/or the like).

Referring to FIGS. **1**-**7**, the management interface **700** may be configured as a window interface being displayed by the display device of the user interface **114** of the backend device **110**. The management interface **700** may include at least a devices table **710** and a data job diagram **720**. The devices table **710** and/or the data job diagram **720** may be arranged in any suitable positions, sizes, orientation within the management interface **700**. The management interface **700** may include an option to purchase additional user devices (such as user devices **140***a*-**140***n*) from a third-party cores (such the a user core **150**) provider when the available user devices **140***a*-**140***n* connected to the network **130** may not be enough to process the computing task (e.g., the source data).

The devices table **710** may list a plurality of user devices (e.g., the user devices **140***a*-**140***n*) connected to the backend device **110**. In other words, the devices table **710** may display the available user devices as identified with respect to block B**510**. Each of the available user devices may be listed in separate entries (e.g., rows) such as, but not limited to, a first entry **740***a*, a second entry **740***b*, a third entry **740***c*, a fourth entry **740***d*, and a fifth entry **740***e*. Additional entries may be displayed in the devices table **710**.

Each of the available user device may be identified by an unique identification such as, but not limited to, the IP addresses listed in the IP address column **715**. For example, each of the entries **740***a*-**740***e* may include a corresponding IP address identified in the IP address column **715**. Each IP address may be associated with two or more of the user devices. For each of the entries **740***a*-**740***e*, a total number of cores is displayed in the total cores column **730** according to some embodiments. Each of the user device may be associated with at least one core. For example, the user device associated with the first entry **740***a* (with IP address 75.82.189.xx) may include 32 cores. In another example, the user device associated with the fifth entry **740***e* (with IP address 79.61.525.xx) may include only 4 cores.

The execution time (as shown in the execution time column **735**) associated with each IP address may be displayed in the devices table **710**. In some embodiments, the execution time may be an average time required to process one of the assigned data threads. Thus, the execution time associated with each IP address may depend on the processing power (e.g., the higher processing power may be associated with faster execution time). For example, the user device associated with the first entry **740***a* (with IP address 75.82.189.xx) may require 25.2 ms to execute each data thread assigned. In another example, the user device associated with the fifth entry **740***e* (with IP address 79.61.525.xx) may require 41.7 ms to execute each data thread assigned. In other embodiments, the execution time may take into account network conditions. For example, the execution time may be measured from transmission of the data thread by the backend device **110** to the receiving of the thread result, thus taking into account network transmission delays.

In some embodiments, the devices table **710** may include a number of data threads processed and/or a number of data threads assigned to the corresponding IP address by the backend device **110**. For example, the user device associated with the first entry **740***a* (with IP address 75.82.189.xx) may be assigned 475 data threads to process, all of which have been processed. In another example, the user device associated with the fifth entry **740***e* (with IP address 79.61.525.xx) may be assigned 100 data threads to process, 10 of which have been processed.

In some embodiments, the devices table **710** may include a frames per second (FPS) as indicated in the FPS column **755** corresponding to each IP address listed in the IP address column **715**. FPS indicates performance in consuming the job results, which is determined by the backend device **110** based

on the thread result **460** from each of the available user devices. The job results may be transmitted to the user devices **140***a*-**140***n* for consumption. The job results may be weighting values associated with each vertex (e.g., the vertices **320***a*-**320***h*) within a target space (e.g., the target space **300**) for live 3-dimensional streaming. Increase in processing capabilities and network conditions may lead to higher FPS, vice versa.

The data job diagram **720** may illustrate the source data and/or the data job. In some embodiments, a data job may be processing graphics data. Specifically, the data job shown in the data job diagram **720** is to process a frame **795** including captured data **750**. As described each data job may be segmented into a plurality of data threads (e.g., data threads **760**-**775**). Each data thread may be associated with a disparate area within the frame **795**.

In further embodiments, the management interface **700** may include graphs and diagrams that graphically illustrate the processed data jobs with respect to the overall number of data jobs, time, number of cores, number of available/bus user devices, a combination thereof, and/or the like.

FIG. **8** is a process flowchart illustrating an example of a data processing method **800** according to various embodiments. The data processing method **800** may be performed by a user device (e.g., the user devices **140***a*-**140***n*). Referring to FIGS. **1**-**8**, the user device **140***n* may connect to the backend server **110** at block B**810**. In various embodiments, the user device **140***n* may connect (via the user network device **163**) to the backend device **110** by assessing a website hosted by the backend device **110** or by logging onto the backend device **110**. In other words, the user device **140***n* may be connected to the backend device **110** when it has been identified by the backend device **110** according to block B**510**.

Next at block B**820**, the user device **140***n* may receive a data block including at least one data thread **460**, there the data block is set to be the current data block. In some embodiments, the backend device **110** may periodically push the data blocks/threads to the user devices **140***a*-**140***n* in the manner described. In other embodiments, each of the user devices **140***a*-**140***n* may transmit a request to the backend device **110** (when data processing is complete) to receive a new data block/thread to process, in a pull. The data sent to be backend devices **140***a*-**140***n* may be based on a prioritized list of data blocks/threads in the manner described.

Next at block B**830**, the user device **140***n* may be configured to process the current data block. In some embodiments, processing the current data block may include determining the weighting value for a color associated with an area of the frame, the area corresponding to a vertex (e.g., the vertices **320***a*-**320***h*) within the target space **300**. Next at block B**840**, the user device **140***n* may send block result to the backend server **110**. The block result may include at least one data thread result **470**.

Next at block B**850**, the user device **140***n* may determine whether an additional data block has been received from the backend device **110**. When no additional data block has been received from the backend device **110** by the user device **140***n*, the user device **140***n* may standby at block B**860** (B**850**: NO). On the other hand, whereas at least one additional data block has been received from the backend device **110** by the user device **140***n*, the user device **140***n* may be configured to set the additional data block as the current data block at block B**880** (B**850**:NO) to be processed at block B**830**.

After connecting to the backend device **110** at block B**810**, the user device **140***n* may receive a first job result from the backend device **110** for consumption at block B**895**. The first job result may be based on block results outputted by user devices (e.g., the user device **140***a*, the user device **140***b*, . . . , the user device **140***n*−1) other than the user device **140***n*. For example, the first job result may be determined based on data threads/blocks processed previously by other user devices before the user device n **140***n* is connected to the backend device.

After sending the block result to the backend server **110** at block B**840**, the user device **140***n* may receive a second job result from the backend device **110** for consumption at block B**890**. The second job result may be based on block results outputted by user devices (e.g., the user device **140***a*, the user device **140***b*, . . . , the user device **140***n*−1) as well as the user device **140***n*.

When the user device **140***n* is standing by at block B**860** as it does not receive any data blocks to process, the user device **140***n* may receive a third job result from the backend device **110** for consumption at block B**870**. The third job result may be based on block results outputted by user devices (e.g., the user device **140***a*, the user device **140***b*, . . . , the user device **140***n*−1) other than the user device **140***n*.

The job results (e.g., the weighting values associated with the vertices **320***a*-**320***h*) may be used to determine a 3-dimensional projection of the target space **300** for outputting live 3-dimensional videos by the user device interface **164**.

FIG. **9** is a process flow chart illustrating an example of a GPU-oriented distributed data processing method **900** according to various embodiments. Referring to FIGS. **1**-**9**, the GPU-oriented distributed data processing method **900** may be particular implementations of the distributed data processing method **200**, the data processing method **800**, and/or related systems and processes described herein. For example, the GPU-oriented distributed data processing method **900** may correspond to block B**830** of data processing method **800**. The GPU-oriented distributed data processing method **900** may be implemented with user devices such as, but not limited to, the user devices **140***a*-**140***n*. In particular embodiments of the GPU-oriented distributed data processing method **900**, at least one GPU may be implemented as the user core **150** of the user devices.

First at block B**910**, the user device (via its processing unit **160** or its GPU core) may identify at least one portion of source data corresponding to data block received (e.g., at block B**830**), the source data being formatted in GPU-compatible format for processing by the GPU of the user device. The source data may be encoded or formatted according to GPU-compatible format (by the backend device **110** or by the data source **120**) for processing by the GPUs of the user devices. For example, shader language standards may be used for GPU processing. The source data may be encoded or otherwise formatted into elements such as, but not limited to, geometry, vertices, textures, normals, the code for the shader language itself, and/or the like. Once converted, the source data may be streamed or otherwise sent into the shader for GPU processing. In particular embodiments, the source data (e.g. images or frames of videos) may be formatted into textures (as compared to other elements) for fast GPU processing (e.g., at 120 fps).

The data block may include at least one data thread, each data thread may include metadata (e.g., location of the actual source data, particular identifiers of the portions of the source data, processing parameters, and/or the like) corresponding to the source data (e.g., an image or a frame of a video). Based on the location (e.g., URL data) of the source data and the identifier of the portion of the source data relating to this data thread (e.g., coordinates of an area of the image/frame), the user device may locate and retrieve the relevant portions of the source data for processing from the data sources **120**. This

may occur once the source data has been received at the user device in shader (or other suitable GPU-compatible format) format.

Next at block B**920**, the user device may process, with at least one GPU, the at least one portion (as identified in block B**910**) of the source data in GPU-compatible format (e.g., in shader language as described). Generally, the processes may relate to any processes involving a string of math functions, which may also take advantage of OpelGL optimized pipeline for matric math and low level functions to complete in an efficient manner.

In some particular embodiments, such processes may involve projecting a 2-dimensional image (which is formatted in shader language as a texture or other suitable elements) to a set of vertices (e.g., vertices **320***a*-**320***h*) defined within a target space (e.g., the target space **300**). For example, a set of all vertices of the target space or a portion thereof (e.g., a subset of the entire set of vertices, the subset of vertices may be arranged in suitable manner such as in a line, a plane, in a volume, or the like) may be set with the data blocks/threads or separately via other data units to the user devices. The user device may project at least one of the vertices received to an area of the frame/image as identified by the metadata sent as the data blocks/threads.

In other or further particular embodiments, the user device may determine, with its GPU, display characteristics of an area of the frame/image, which corresponds to at least one vertex. By way of illustrating with a non-limiting example, the user device may be configured to average a number of surrounding pixels with respect to a target pixel (which may be an area of an image identified by the data thread) to output the average as the color for the target pixel.

Next at block B**930**, the user device may render, with the at least one GPU, results of the processing (e.g., at block B**920**) to the user interface **164** (e.g., the display device of the user interface **164**) of the user device. After processing is completed, the GPU may render the results to the screen of the user device. Next at block B**940**, the user device may copy and send the rendered results back to the backend device **110** or another remote storage for aggregation any computing the job outcome in the manner described. Accordingly, the processed results may be readily and speedily transmitted out of the GPU and the user device.

FIG. **10** is a process flow chart illustrating another example of a GPU-oriented distributed data processing method **1000** according to various embodiments. Referring to FIGS. **1**-**10**, the GPU-oriented distributed data processing method **1000** may be particular implementations of the distributed data processing method **200** and/or related systems and processes described herein. For example, the GPU-oriented distributed data processing method **1000** may correspond to blocks B**240** and B**250** of the distributed data processing method **200**. The GPU-oriented distributed data processing method **1000** may be implemented with the backend device **110**. In particular embodiments of the GPU-oriented distributed data processing method **1000**, at least one GPU may be implemented as the user core **150** of the user devices.

First at block B**1010**, the backend device **110** (or the data source **120**, or another device) may provide source data in GPU-compatible format for distributed processing by a plurality of GPUs. Each GPU may be associated with a user device. For example, shader language standards may be used to program GPU processing. The source data may be encoded or otherwise formatted into elements such as, but not limited to, geometry, vertices, textures, normals, and the code for the shader language itself. Once converted, the source data may be streamed or otherwise sent into the shader for GPU processing. In particular embodiments, the source data may be converted into textures (as compared to other elements) for fast GPU processing (e.g., at 120 fps).

Next at block B**1020**, the backend device **110** may send at least one data block corresponding to at least one portion of the source data to each of the plurality of GPUs in the manner such as, but not limited to, in block B**240**. The at least one data block may include at least one data thread, each data thread may include metadata (e.g., location of the source data, particular identifiers of the portions of the source data, processing parameters, and/or the like) corresponding to the source data (e.g., an image or a frame of a video). Based on the location (e.g., URL data) of the source data and the identifier of the portions of the source data relating to this data thread (e.g., coordinates of an area of the image), the user device may locate and retrieve the relevant portions of the source data for processing. This may occur once the source data has been received at the user device in shader format.

Next at block B**1030**, backend device **110** may receive results from each of the plurality of GPUs, each result has been rendered to the user interface **164** associated with each of the plurality of GPUs in a manner such as, but not limited to, block B**250**. The user device may process, with at least one GPU, the at least one portion (as identified in block B**910**) of the source data in GPU-compatible format (e.g., in shader language as described) in a manner such as, but not limited to, described with respect to block B**920**. The GPUs may then render the results to the user interface such as described with respect to B**930**. and copied and transmitted to the backend device **110** at block B**940**.

Various particular implementations of the asynchronous computing web framework may be related to image/video processing (e.g., filtering images, facial recognition in images, 3-dimensional projections, and the like), processing of gene data, currency arbitrage data, weather data, vertex data, chemical formulas, or other arbitrary data required by distributed computing tasks. In other words, the source data may be any parallel data set. In some embodiments, different data sets may take advantage of geographic distribution of the user devices **140***a*-**140***n* to enable solutions for big data problems.

In some additional embodiments, the distributed computing processing framework **100** may be implemented to solve currency exchange arbitrage algorithms (for example, using the Bellman Ford shortest path algorithm, which determines infinite loop cycles when a log of the currency exchange rates are taken). In some embodiments, each of the user devices **140***a*-**140***n* may be associated with a currency. The associated currency (the data of which may be in the form of data blocks/threads) may be assigned by the backend device **110** based on geographical location associated with each of the user devices **140***a*-**140***n* (i.e., each of the user devices **140***a*-**140***n* may be assigned the currency used in the geographical location). As such, when a user device **140***a*-**140***n* detects an infinite loop cycle corresponding to the assigned currency, it may be closer to a financial institution which can trade the assigned currency most efficiently. For example, the user device may be in or proximal to the financial institution. The user devices **140***a*-**140***n* may be connected to the backend device **110** using a browser or connecting to a social network using the distributed computing framework **100** in the background for data processing, which the users of the user devices **140***a*-**140***n* are unaware. Accordingly, such distributed computing framework **100** may out-scale centralized arbitrage super computers as bandwidth capabilities of the network **130** increase. The distributed computing framework

100 (e.g., the backend device 110) may be implemented with social networks (as the network 130).

In some additional embodiments, raw video/image data (e.g., as the source data) may be spread out and encoded in parallel overlapping segments (e.g., received at block B210, partitioned at block B220, stored at block B230, and sent at block B240), each segment may be treated as a data block/thread to be processed by a separate one of the user devices 140*a*-140*n*. As such, any data block/thread may complete processing (e.g., at block B250-B260) before any encoding system can finish encoding an entire video/image. As such, all the segments of the raw video/image data may be done at once, around the same time. Servers with large amount of user devices 140*a*-140*n* (e.g., social network sites) may provide unprecedented amount of processing power.

In some additional embodiments, gene sequence data may be receive (e.g., at block B210), partitioned (e.g., at block B220), and stored (e.g., at block B230) as data blocks/threads. The data blocks/threads may be sent to the user devices 140*a*-140*n* (e.g., at block B240) for processing (e.g., at block B250). In particular, the gene sequence data may be divided based on gene classifications (at block B220) for parallel processing. Search windows may be provided across strings of DNA and sent into the distributed computing framework 100 for automated classification.

In other additional embodiments, images stored on social networks may be processed slowly over time to automatically identify any arbitrary corners or features, then send to the user devices 140*a*-140*n* to identify the corners or features when sufficient number of the corners or features have been identified together to form objects and people. Overtime, all objects and people can be automatically learned by the distributed computing network 100, which is constantly being taught by its users' inputs. The identification processes may be achieved virtually costless to the social networks, as the identification processes are completed by the user devices 140*a*-140*n* connected to the network 130 (e.g., the social networks).

Various embodiments described above with reference to FIGS. 1-8 include the performance of various processes or tasks. In various embodiments, such processes or tasks may be performed through the execution of computer code read from computer-readable storage media. For example, in various embodiments, one or more computer-readable storage mediums store one or more computer programs that, when executed by a processor cause the processor to perform processes or tasks as described with respect to the processor in the above embodiments. Also, in various embodiments, one or more computer-readable storage mediums store one or more computer programs that, when executed by a device, cause the computer to perform processes or tasks as described with respect to the devices mentioned in the above embodiments. In various embodiments, one or more computer-readable storage mediums store one or more computer programs that, when executed by a database, cause the database to perform processes or tasks as described with respect to the database in the above embodiments.

Thus, embodiments include program products including computer-readable or machine-readable media for carrying or having computer or machine executable instructions or data structures stored thereon. Such computer-readable storage media can be any available media that can be accessed, for example, by a general purpose or special purpose computer or other machine with a processor. By way of example, such computer-readable storage media can include semiconductor memory, flash memory, hard disks, optical disks such as compact disks (CDs) or digital versatile disks (DVDs), magnetic storage, random access memory (RAM), read only memory (ROM), and/or the like. Combinations of those types of memory are also included within the scope of computer-readable storage media. Computer-executable program code may include, for example, instructions and data which cause a computer or processing machine to perform certain functions, calculations, actions, or the like.

The embodiments disclosed herein are to be considered in all respects as illustrative, and not restrictive. The present disclosure is in no way limited to the embodiments described above. Various modifications and changes may be made to the embodiments without departing from the spirit and scope of the disclosure. Various modifications and changes that come within the meaning and range of equivalency of the claims are intended to be within the scope of the disclosure.

What is claimed is:

1. A method for processing data, the method comprising:
receiving, by a backend device, source data related to a target space, the target space is defined by a plurality of vertices;
partitioning, by the backend device, the source data into a plurality of data threads, each of the plurality of data threads is associated with at least one of the plurality of vertices;
sending, by the backend device, at least one of the plurality of data threads to each of a plurality of user devices;
receiving a plurality of data thread results from the plurality of user devices, each of the plurality of data thread results corresponds to at least one of the plurality of data threads, wherein each of the plurality of data thread results comprises at least one display characteristic associated with at least one of the plurality of vertices; and
determining, by the backend device, a job outcome for the source data based on the plurality of data thread results;
wherein the job outcome comprises weighting factors for display characteristics associated with each of the plurality of vertices.

2. The method of claim 1, wherein:
the source data is a captured video frame.

3. The method of claim 2, wherein:
partitioning of the source data into the plurality of data threads comprises partitioning the captured video frame into a plurality of areas based on metadata associated with the captured video frame and the plurality of areas, each of the plurality of areas corresponds to one of the plurality of data threads.

4. The method of claim 2, wherein the partitioning of the source data into the plurality of data threads comprises partitioning the source data based on pixels of the source data.

5. The method of claim 2, wherein the frame is an image of a target space.

6. The method of claim 5, wherein;
the target space comprises of a plurality of vertices; and
each of the plurality of vertices corresponds to a 3-dimensional portion of the target space.

7. The method of claim 6, wherein:
each of the plurality of data threads is associated with at least one of the plurality of vertices; and
each of the plurality of data threads corresponds to an area of the image.

8. The method of claim 7, wherein each of the data thread results is determined by determining a weighting value associated with at least one display characteristics associated with the area of the image.

9. The method of claim 8, wherein the display characteristics comprises at least a color associated with the area of the image.

10. The method of claim 6, wherein the image captures at least some of the plurality of vertices.

11. The method of claim 1, wherein determining the job outcome comprises:

receiving, by the backend device, the plurality of data thread results from the plurality of user devices; and

determining the job outcome for the data job based on the received plurality of data thread results.

12. The method of claim 1, wherein sending the at least one of the plurality of data threads comprises:

determining at least one of processing power and network conditions for each of the plurality of user devices; and

assigning each of the plurality of user devices at least one of the plurality of data threads based on at least one of the processing power and the network conditions.

13. The method of claim 1, further comprising formatting the source data into graphic processing unit (GPU)-compatible format, wherein each of the plurality of data thread results is determined by at least one GPU associated with each of the plurality of user devices.

14. The method of claim 13, wherein the GPU-compatible format is associated with shader language.

15. The method of claim 14, wherein the source data is formatted into at least one of the following elements: geometry, vertices, textures, normals, and code for the shader language.

16. The method of claim 1, further comprising receiving, by the backend device, the plurality of data thread results after the plurality of data thread results have been rendered to the display screen associated with each of the user devices.

17. The method of claim 1, further comprising streaming the job outcome to a Content Delivery Network (CDN) in the form of depth videos.

18. An apparatus for processing data, the apparatus comprising:

a backend device, the backend device is configured to:

receive source data related to a target space, the target space is defined by a plurality of vertices;

partition the source data into a plurality of data threads, each of the plurality of data threads is associated with at least one of the plurality of vertices;

send at least one of the plurality of data threads to each of a plurality of user devices;

receive a plurality of data thread results from the plurality of user devices, each of the plurality of data thread results corresponds to at least one of the plurality of data threads, wherein each of the plurality of data thread results comprises at least one display characteristic associated with at least one of the plurality of vertices; and

determine a job outcome for the source data based on the plurality of data thread results;

wherein the job outcome comprises weighting factors for display characteristics associated with each of the plurality of vertices.

19. A non-transitory computer-readable storage medium storing program instructions that, when executed, causes a processor to:

receive source data related to a target space, the target space is defined by a plurality of vertices;

partition the source data into a plurality of data threads, each of the plurality of data threads is associated with at least one of the plurality of vertices;

send at least one of the plurality of data threads to each of a plurality of user devices;

receive a plurality of data thread results from the plurality of user devices, each of the plurality of data thread results corresponds to at least one of the plurality of data threads, wherein each of the plurality of data thread results comprises at least one display characteristic associated with at least one of the plurality of vertices; and

determine a job outcome for the source data based on a plurality of data thread results;

wherein the job outcome comprises weighting factors for display characteristics associated with each of the plurality of vertices.

20. A method for processing data by a user device, the method comprising:

receiving, from a backend device, a data thread, the thread corresponds to at least one of an image or a video frame capturing at least one of a plurality of vertices defining a target space;

determining a data thread result, the data thread result comprising at least one display determining a data thread result, the data thread result comprising at least one display characteristic associated with each of the at least one of the plurality of vertices;

sending the data thread result to the backend device;

receiving, from the backend device, a job outcome, wherein the job outcome is determined based, at least in part, on the data thread result; and

displaying a 3-dimensional projection of the target space based on the job outcome;

wherein the job outcome comprises weighting factors for display characteristics associated with each of the plurality of vertices.

21. The method of claim 20, wherein the data thread results are determined by:

rendering the data thread results to a display screen of the user devices; and

copying the data thread results rendered to the display screen.

* * * * *